INSTRUCTION MANUAL

For

PROTECTIVE RELAY TEST SET

MODEL EPOCH-10®

It is essential that this instruction book be read thoroughly before putting the equipment in service.

Part No 11983
Rev. 2

APPRECIATION

We are indebted to the manufacturers of protective relays, who have given their time and advice in the preparation of this instruction book.

And, we also express our gratitude to engineers all over the country for their counsel and suggestions towards the testing and maintenance of protective relays.

IMPORTANT

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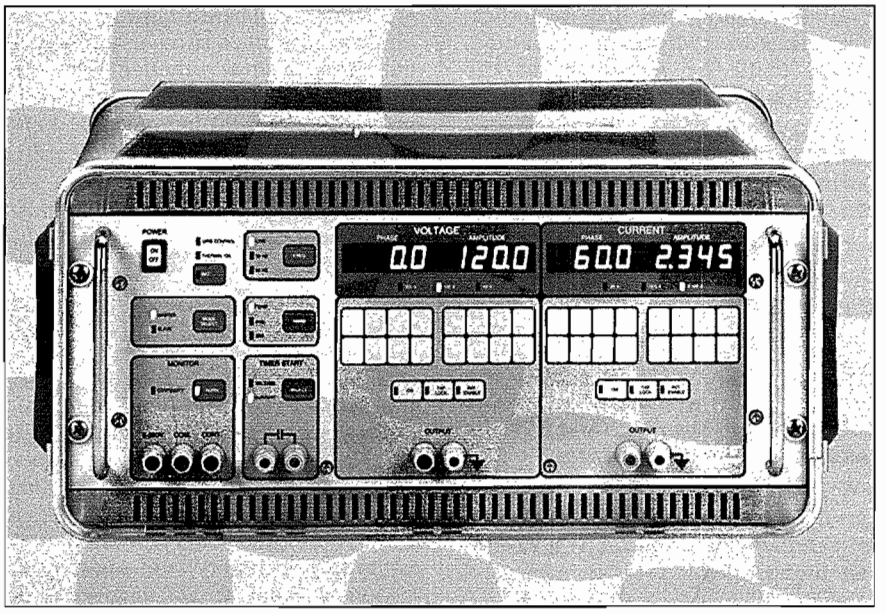


MULTI-AMP® EPOCH-10®

- **Microprocessor-based relay test equipment**
- **Industry standard**
- **IEEE-488 GPIB**
- **Cornerstone of protective relay testing**

Protective Relay Test Set

DESCRIPTION

The Multi-Amp® EPOCH-10® relay test set integrates advanced microprocessor-based technology with decades of experience in the application, design and manufacture of equipment for calibrating protective relays to provide an extremely accurate, versatile and easy-to-use relay test set.

Intended for field use at substations and power plants, the EPOCH-10 is a portable, lightweight and very rugged test set. Its versatility makes it ideal for use in the relay shop, in the test laboratory or on the production line.

A single EPOCH-10 provides a variable current output, a variable voltage output, adjustable phase-angle settings, a harmonic generator and comprehensive control and monitoring circuits. Interconnecting two or three units creates an open-delta three-phase test system, or a complete three-phase test system consisting of six independently adjustable, phase-shiftable outputs, three voltages and three currents. The EPOCH-10 can be used with other members of the EPOCH® Family to provide more comprehensive facilities when required.

APPLICATIONS

With the modular design of the EPOCH family, you can select the unit(s) with the capabilities and features required by your present application, and add

IEEE Device Number	Relay Types	Specify
50	Instantaneous Overcurrent*	One EPOCH-10
51	Overcurrent*	
67	Directional Overcurrent*	
67N	Ground Directional Overcurrent*	
21	Distance (1ϕ)	
32	Directional Power (1ϕ)	
40	Loss of Field	
87	Differential	Two EPOCH-10s
59	Overvoltage	
27	Undervoltage	
25	Synchronizing	
21	Distance (open-delta)	
21	Distance (3ϕ WYE)	Three EPOCH-10s
32	Directional Power (3ϕ)	
46	Negative Sequence Overcurrent	
81	Frequency	One EPOCH-10
25	Autosync/Syncverifier Synchronizing	One EPOCH-30

*For higher currents (up to 187 amperes) or higher volt-amperes, use EPOCH-20® (600 VA) or EPOCH-II® (1000 VA) with the EPOCH-10.

to your original unit(s) as your testing needs expand. The table lists the different types of relays by IEEE device numbers and the different EPOCH-10 combinations that would be required to test them.

When performing automated relay testing with a computer and an EPOCH-10, Multi-Amp PulseMaster® software gives you the option of using the computer to perform timing tests. This eliminates the requirement for a separate timer. The accuracy of the computer-based timing method is approximately ±20 ms with IBM PCs and compatibles. When high-speed or high-accuracy timing is required, use either the EPOCH-30®, EPOCH-40® or the EPOCH-V®.

FEATURES AND BENEFITS

Many standard features are incorporated in each EPOCH-10 to reduce setup time, simplify test procedures and increase accuracy. Among these are:

- Each EPOCH-10 is a self-contained test set and provides variable current, variable voltage, phase shifting, control and monitoring functions.
- Current, voltage and phase angle settings are each independently incremented by 4-digit raise and lower pushbutton controls that automatically increment to the next decade whenever a decade-changing value is reached.
- Amplitude and phase angle of the output current and voltage are displayed on large, high-intensity LED displays that remain active even when the test set is under automatic computer control.
- Autoranging is provided on amplitude controls to provide resolution corresponding to the output magnitude.
- Automatic output-current tap selection provides impedance matching to load.
- Typical accuracy of voltage and current outputs is ±0.5% of setting.
- Phase angle accuracy is typically ±0.2% of setting.
- Output frequency is synchronized to input line or crystal controlled at 50/60 Hz.
- Audible alarm and display indication are given whenever amplitude, phase angle or waveform of the outputs is in error.
- A harmonic generator circuit converts the current and potential outputs to either a second, third or fifth harmonic.
- Output-current source has a continuous duty cycle rating of 100 VA.
- Output-potential source has a continuous duty cycle rating of 75 VA.
- Three output-current ranges are provided, with a resolution of 0.001 ampere on the low range and 0.01 ampere on the two upper ranges.
- Three output-potential ranges are provided, with a resolution of 0.01 volt on the low range and 0.1 volt on the two high ranges.
- The output current of two or three test sets can be connected in parallel to increase the maximum current available to 50 amperes (two units) or to 75 amperes (three units).
- The output potential of two test sets can be summed together to increase the maximum potential available if the load is not grounded.
- With two or three EPOCH-10s used together, any one of the four or six outputs can be the reference against which the phase angle of all the others is set.
- Optional IEEE-488 interface transforms the unit into an automatic, programmable test system.
- Numerous protective circuits are incorporated, including thermal pro-tection of the power amplifiers and overvoltage protection of the input circuit.
- An isolated contact monitoring and sensing circuit is incorporated to monitor dry contacts, SCR conduction and voltage signals.
- A circuit is incorporated to initiate an external timer simultaneously with any output.
- Tough polyethylene-plastic, sealed enclosure provides a high-shock and vibration resistance. Rubber sealed lids protect the test set from water and dust intrusion.
- Completely compatible with all EPOCH units.
- For maximum flexibility in controlling the outputs, a three-mode output initiating circuit is provided. When desired, either the current or potential output, or both outputs, can be independently switched "on" and/or "off."

When two or three EPOCH-10s are used together, any or all can be initiated simultaneously by using the initiating switch on any one of the test sets.

- To monitor operation of the trip contact or trip SCR in the relay under test, a continuity light and an audible tone generator are provided. Additionally, an isolated circuit is provided that is voltage sensing and can monitor solid-state logic signals. This circuit senses a positive-going signal and sounds the tone generator and illuminates the continuity light upon application of the 5- to 250-volt ac or dc signal.
- A special harmonic generator is incorporated to test relays that include harmonic restraint elements.

This circuit provides the capability of converting the output current and potential to either a second, third or fifth harmonic of the input line or crystal oscillator frequency. Thus, by simple use of a panel switch, the test technician can select a 50-, 60-, 100-, 120-, 150-, 180- or 300-Hz current and potential output.

When testing the harmonic restraint element of a transformer differential relay, two EPOCH-10s are required: one to provide the fundamental current and the other to provide the desired harmonic current. The two currents are connected in parallel to produce the desired test current.

- Input line and dc power supply are fuse protected. Additionally, overvoltage protection is provided on the input line circuit. The power amplifiers are forced-air cooled and are protected by thermal overload relays. Audio and visual alarms indicate whenever the current or potential outputs are overloaded.
- To simulate the worst of field conditions, the EPOCH-10 has been tested and qualified in accordance with MIL-STD-810 for temperature, shock and vibration.

SPECIFICATIONS

Input

Input Voltage (specify one)

115 V ±10%, 1ϕ, 50/60 Hz
OR
230 V ±10%, 1ϕ, 50/60 Hz

Output

Output Frequency

- Synchronized to input power source
- Synchronized to external frequency source (EPOCH-30 may be used to establish the frequency output of the EPOCH-10. Standard EPOCH-30 range is 10.000 to 99.999 Hz. EPOCH-10 full output power is available from 40 to 80 Hz. Beginning at 40 Hz, output power is linearly derated to 50% of output tap and 50% of output power at 20 Hz.)
- 60 Hz crystal controlled
- 50 Hz crystal controlled

Accuracy

- Synchronized, tracks input frequency
- Synchronized to EPOCH-30 ±10 ppm or 0.00006 Hz at 60 Hz
- ±0.006 Hz for 60 Hz crystal controlled (±0.01%)
- ±0.005 Hz for 50 Hz crystal controlled (±0.01 %)

Output Current: To meet a variety of test circuit impedances, three output ranges are provided. Only a single pair of output terminals is needed since impedance matching to the load is automatically performed by the microprocessor. Amplitude is adjusted by 4-digit, autoranging pushbutton control, with a large LED display of setting.

Ranges (auto-impedance matched)
0.00 to 25.00 A at 4 V max.
0.00 to 12.50 A at 8 V max.
0.000 to 3.125 A at 32 V max.

Resolution
Upper Two Ranges: 0.01 A
Low Range: 0.001 A

Rating: 100 VA

Duty Cycle: Continuous

Over-Range: A minimum of 20% amplitude over-range is available on each tap to reduce unnecessary tap changing and extend output capability. Duty cycle will vary with percent of over-range.

Accuracy
Typical: ±0.5% of setting or ±0.1% of range, whichever is greater

Maximum: ±1% of setting or ±0.1% of range, whichever is greater

Distortion: Less than 1% typical, 2% maximum

Alarm will indicate when amplitude, phase angle or waveform is in error.

Current Phase Angle Control: Angle is adjusted by 4-digit, pushbutton control, with large LED display of setting.

Range: 0.0 to 359.9°

Resolution: 0.1°

Accuracy: ±0.2° typical, ±0.5° max.

Output Voltage

Ranges (automatic range selection)
0.0 to 300.0 V at 0.25 A
0.0 to 150.0 V at 0.5 A
0.00 to 40.00 V at 0.25 A

Resolution
Upper Two Ranges: 0.1 V
Low Range: 0.01 V

Rating: 75 VA

Duty Cycle: Continuous

Over-range: The 150-volt range can be over-ranged up to 155-volt and the 300-volt range up to 310 V.

Accuracy
Typical: ±0.5% of setting or ±0.1% of range, whichever is greater
Maximum: ±1% of setting or ±0.1% of range whichever is greater.
Distortion: Less than 1% typical, 2% maximum

Alarm will indicate when amplitude, phase angle or waveform is in error.

Note: Accuracy may be greater than 1% for frequencies less than 40 Hz.

Regulation: Better than 0.5% (line/load)

Voltage Phase Angle Control: Angle is adjusted by 4-digit, pushbutton control, with large LED display of setting.

Range: 0.0 to 359.9°

Resolution: 0.1°

Accuracy: ±0.2° typical, ±0.5° max.

Temperature

Operating: 32 to 122° F (0 to 50° C)

Storage: –13 to +158° F (–25 to 70° C)

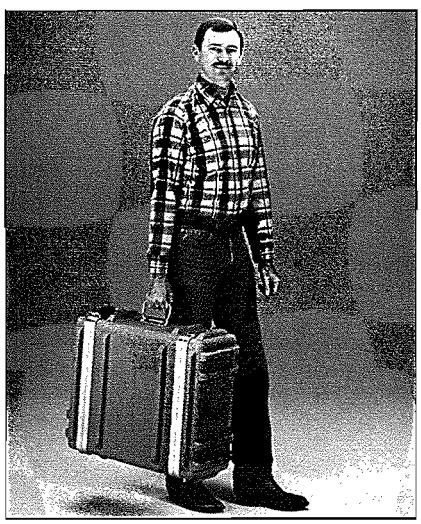
Dimensions

With Lids On
10.75 H x 21 W x 24.5 D in.
273 H x 533 W x 622 D mm

With Lids Off
10.75 H x 21 W x 18.5 D in.
273 H x 533 W x 470 D mm

Weight

With Lids On: 56 lb (25.5 kg)
With Lids Off: 50 lb (22.5 kg)



All EPOCHs (except the EPOCH-V) are housed in a rugged, polyethylene case custom-designed to withstand rugged field use.

ORDERING INFORMATION

Item	Cat. No.
EPOCH-10	
115-volt input	EPOCH-10-115/STD
IEEE interface and 115-volt input	EPOCH-10-115/IEE
230-volt input	EPOCH-10-230/STD
IEEE interface and 230-volt input	EPOCH-10-230/IEE
IEEE interface and 115-volt input without enclosure for rack mounting the unit	EP10-115/IEE/RK
IEEE interface and 230-volt input, without enclosure	EP10-230/IEE/RK
115-volt input, without enclosure	EP10-115/RK
230-volt input, without enclosure	EP10-230/RK

Item (Qty)	Cat. No.
Included Accessories	
Carrying case (1)	11436
Fuses: 10 A, 250-volt (5)	11333
Ground lead (1)	11258
Interconnect cable (1)	10838
Test leads	
Voltage (2 pr)	1282
Current (1 pr)	15922
Power cord (1)	6828
Instruction manual (1)	11987

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DESCRIPTION OF CONTROLS

This section of the instruction manual describes the function of all the various controls, switches, pushbuttons, binding posts, etc., which are located on the Multi-Amp® Model EPOCH-10®. All controls and outputs are clearly marked and logically grouped so that continual reference to the instruction manual should not be necessary after the operator has become acquainted with the operation of the test set as well as the test system.

FRONT PANEL

Control Section:

The left section of the front panel is devoted to the power on, initiate control, selection of the internal oscillator, MASTER/SLAVE control, harmonic selection, contact monitor and timer start controls. A description of each of these controls follows:

POWER ON/OFF Switch	Use to energize input to Model EPOCH-10. Also functions as a circuit breaker for input protection.
INITIATE Control Switch	This switch is used in conjunction with the INITIATE control circuitry to simultaneously energize or de-energize selected outputs of the test set or outputs of more than one Model EPOCH-10 when used. The INITIATE Switch is used in conjunction with the Output INITIATE Switches in the Voltage and Current sections to control the operation of the test set (see descriptions of these switches for further explanation). When the Voltage and/or Current Output INITIATE Switch(es) are in the initiate position (red lamp(s) glowing) and the desired outputs are set with the pushbutton controls; when the INITIATE Switch in the Control Section is pressed, the appropriate outputs become energized. Additionally, a dry contact simultaneously closes at the TIMER START Binding Posts to start an external timer (see description under TIMER START). Once the test set is initiated, the outputs will remain energized until the INITIATE Control Switch is pressed again or until an operation is sensed by the MONITOR circuit on the MASTER Unit. Also, pressing the output INITIATE Switch of the selected output channel will de-energize the output, however, repressing the selected output INITIATE Switch will re-energize that output, as long as the INITIATE Control Switch is energized.

When using more than one Model EPOCH-10, selected outputs of all units can be initiated from the MASTER Unit by pressing and releasing the INITIATE Control Switch. To de-initiate all initiated outputs on all units, simply press and release the INITIATE Control Switch on the MASTER Unit.

GPIB CONTROL Lamp

When lamp is glowing, this indicates the test set(s) are being controlled by an external controller such as a microprocessor or computer via the optional IEEE-488 BUS. When lamp is glowing, all controls on the front panel are inactive (dead) with the exception of the POWER ON/OFF Switch.

THERMAL OVERLOAD Lamp

To prevent damage to either the voltage source or the current source power amplifiers due to excessive overloads, thermal overload circuitry is incorporated. Should the operator attempt to operate either output in excess of its rating for an extended length of time, the thermal overload circuitry will automatically de-energize the outputs on the test set. The display of the overloaded channel will display "EEEE" and the THERMAL OVERLOAD lamp will glow.

Fan operation will continue to provide the necessary cooling. **If a thermal shutdown occurs, the operator must not switch POWER OFF** so that the fan will continue to operate. After waiting several minutes for the unit to cool, the OVERLOAD lamp will go out and operation of the test set can be resumed.

MASTER/SLAVE Switch

This switch is used when designating the MASTER Unit. By pressing this switch to MASTER position, all other units will become SLAVES to that unit.

FREQUENCY LINE 50 Hz/LINE 60 Hz Switch and Lamp Indicators

This feature allows the operator to select a fixed output frequency of either 50 Hz or 60 Hz. Lamp indicators indicate output frequency. This switch also can be used to select an output frequency dependent upon the power input line frequency. When the LINE lamp glows, the output frequency of the test set is dependent upon the power line frequency. When operating more than one EPOCH-10, the SLAVE Unit(s) will be switched to SLAVE and the MASTER Unit will be switched to LINE, 50 or 60 hertz thereby establishing a common phase reference of the SLAVE Unit(s) to the frequency of the MASTER Unit.

HARMONIC FUND./2nd/3rd Switch and Lamp Indicators

This switch provides the capability of converting the output current and voltage to either a second or third harmonic of the selected output frequency. Thus, by pressing the switch, the operator can select 60, 120 or 180 hertz (50, 100 or 150 hertz on 50 hertz output) current and voltage outputs.

NOTE: To conduct harmonic restraint tests on a differential relay requires two EPOCH-10's.

MONITOR Binding Posts, HORN ON/OFF Switch and CONTINUITY Lamp

The contact monitor and sensing circuitry is provided for use in observing the output of the relay under test.

When testing an electromechanical or solid-state relay which has a dry contact that completes the trip circuit, the dry contact is connected to the Green CONT. and Black COM. Binding Posts.

If the relay incorporates an SCR, which gates (fires) a trip voltage to complete the trip circuit, the SCR is connected with the anode to the Red 5-250V Binding Post and cathode to the Black COM. Binding Post.

With the HORN Switch in the **ON** position and the contact on the device under test is closed or the SCR is gated, the tone signal sounds and the CONTINUITY lamp glows. When HORN is in the **OFF** position, the CONTINUITY Lamp glows on contact closure.

If the outputs of the test set are in the INITIATE position, the test set will de-initiate the selected outputs when the contacts of the device under test is closed or the SCR is gated. This can be useful when conducting timing tests or determination of instantaneous contact closure.

For static relays utilizing low voltage logic circuit, the 5-250V Red binding post and Black COM. binding post are provided to sense relay operation. These terminals will sense logic voltage from a minimum of 5 volts DC or AC to a maximum of 250 volts DC or AC, and will sound the tone signal and the CONTINUITY Lamp will glow. The Red binding post is used as the positive terminal and the Black COM. binding post for negative.

IMPORTANT:

Caution, do not apply a voltage to the Green and Black binding posts. To do so may result in damage to the monitor circuit.

TIMER START Binding Posts and VOLTAGE/CURRENT Switch and Lamp Indicators

Used in conjunction with the initiate circuitry to provide for starting an external timer. The normally open, dry contact terminals of an external timer (such as Multi-Amp Models EPOCH-IV, EPOCH-V, SST-2 Solid-State Digital Timer and TV-2/Voltage Auxiliary Unit) are connected to the Yellow CONTACTS binding posts.

The operator has the option to select whether the timer is started simultaneously with the initiation of the voltage channel or the current channel.

When the VOLTAGE/CURRENT Switch is in the VOLTAGE position, the indicating lamp on the switch will indicate that the timer will start upon the initiation of the voltage channel. When the switch indicating lamp indicates CURRENT position, the initiation of the current channel starts the timer.

Voltage Section:

The center section of the front panel is devoted to the voltage output controls. The following is a description of each of these controls.

DEGREES Display

This four digit LED display indicates the phase angle of the voltage output.

VOLTS Display

This four digit LED display indicates the amplitude of the voltage output.

CLOCKWISE and COUNTERCLOCKWISE Pushbuttons

Used to set the phase angle relationship of the voltage output against the internal phase reference of the test set. The four-digit pushbutton can increase or decrease the phase angle in increments of:
100 degrees (first pushbutton on the left),
10 degrees (second pushbutton from the left)
1 degree (second pushbutton from the right)
or 0.1 degree (first pushbutton on the right).
Pressing any of the CLOCKWISE pushbuttons increases the phase angle from 0 to 359.9 degrees, i.e. (pressing the 10 degree pushbutton) 0.0, 10, 20. . . 350, 0.0. Pressing any of the COUNTERCLOCKWISE pushbuttons decreases the phase angle from 359.9 to 0, i.e. (pressing the 10 degree pushbutton) 350, 340. . . .20, 10,

0.0. By pressing and holding in the pushbutton, the phase angle will increment or decrement decrementapproximately two digits per second. If desired, the phase angle can be stepped as fast as the operator can press, release and press again on the CLOCKWISE or COUNTERCLOCKWISE pushbuttons.

TAP LOCK Switch

To avoid unnecessary auto tap changing during manual operation, i.e. test voltages slightly greater than 40.00 volts by pressing the TAP LOCK Switch, a given output tap will lock into position and will not autorange.

When using only one Model EPOCH-10, the operator may choose either the voltage or current channel as a zero phase angle reference. Each unit has an internal phase reference to which the voltage and current channels are referenced. It is suggested that one output be selected and set at zero degrees, thereby setting the internal reference and one output channel at the same reference of zero degrees.

When using more than one Model EPOCH-10 test set, the operator can select whichever test set he prefers to be the MASTER Unit (refer to Selection of MASTER Unit described on page 11). Once the MASTER Unit is selected, either the voltage output or current output can be selected as the phase angle reference. For simplicity, it is suggested that whichever output is used as the reference, that its phase angle be set to 0 degrees.

INCREASE and DECREASE Pushbuttons

The four-digit pushbuttons can increase or decrease the voltage output. When in the low range (TAP 1), 0 - 40.00 volts, the first pushbutton on the left will increase the output voltage in 10 volt increments. The second pushbutton will increment in 1 volt increments, the third from the left in .1 volt increments and the last pushbutton from the left (first from the right) will increment in .01 volt increments. When the output exceeds 40.00 volts, i.e. 40.01, the output will autorange to TAP 2 and the decimal point will move to show a display of 40.0 volts. At this point the pushbuttons will change by a factor of 10, i.e. the first pushbutton will now increment 100 volts, the second 10, the third 1 and the last .1 volts. With OUTPUT OFF and TAP LOCK OFF, the test set will autorange from TAP 1 to TAP 2. The voltage output can be stepped as fast as the operator can press, release,

	and press again; or by pressing and holding in the pushbutton the output will automatically increment or decrement two digits per second.
ON/OFF Switch and Lamp	This switch is provided for use in controlling the voltage output. In the OFF position, the red output binding post is open circuited, therefore, the potential output is **OFF** regardless of the position of the INITIATE Control Switch. In the ON position, the voltage output is energized regardless of the position of the INITIATE Control Switch. When the indicating lamp is glowing, the output is energized.
INITIATE Switch and Lamp	When the voltage channel INITIATE Switch is pressed, and the indicating lamp is glowing, the INITIATE Control Switch in the Control Section must be pressed to turn the voltage output ON and OFF.
Voltage Output Red and COM White Binding Posts	Provides for connection to voltage output. The COM White binding post is grounded and should be used as the instantaneous polarity terminal with the Red terminal as non-polarity.
Error Indication and Alarm	Circuitry is incorporated to indicate whenever the amplitude, phase angle, and/or waveform of the voltage source is in error. When the error is detected, the amplitude display will flash and the alarm will sound.

Current Section:

The right section of the front panel is devoted to the current output controls. The following is a description of each of these controls.

DEGREES Display	This four digit LED display indicates the phase angle of the current output.
AMPERES Display	This four digit LED display indicates the amplitude of the current output.
CLOCKWISE and COUNTERCLOCKWISE Pushbuttons	Used to set the phase angle relationship of the current output against the internal phase reference of the test set. The four-digit pushbuttons can increase or decrease the phase angle in increments or decrements of: 100 degrees (first pushbutton on the left), 10 degrees (second pushbutton from the left), 1 degree (second pushbutton from the right) or 0.1 degree (first pushbutton on the right). Pressing any of the CLOCKWISE pushbuttons increases the phase angle from 0 to 359.9

degrees, i.e. (pressing the 10 degree pushbutton) 0.0, 10, 20. . . .350, 0.0. Pressing any of the COUNTERCLOCKWISE pushbuttons decreases the phase angle from 359.9 to 0, i.e. (pressing the 10 degree pushbutton) 350, 340. . . 20, 10, 0.0. By pressing and holding in the pushbutton, the phase angle will increment or decrement approximately every 30 cycles. If desired, the phase angle can be stepped as fast as the operator can press, release, and press again on the CLOCKWISE or COUNTERCLOCKWISE pushbuttons.

When using only one Model EPOCH-10, the operator may choose either the potential or current channel as a zero phase angle reference. Each unit has an internal phase reference to which the voltage and current channels are referenced. It is suggested that one output be selected and set at zero degrees, thereby setting the internal reference and one output channel at the same reference of zero degrees. When using more than one Model EPOCH-10 test set, the operator can select whichever test set he prefers to be the MASTER Unit (refer to Selection of MASTER Unit described on page 11). Once the MASTER Unit is selected, either the voltage output or current output can be selected as the phase angle reference. For simplicity, it is suggested that whichever output is used as the reference have its phase angle set to 0 degrees.

INCREASE and DECREASE Pushbuttons

Used to directly set the output current. The four-digit pushbuttons can increase or decrease the current output. In the low range (TAP 1), 0 - 3.125 amperes, the output can be increased or decreased in increments or decrements of:
1 ampere (first pushbutton from the left),
.1 ampere (second pushbutton from the left),
.01 and .001 amperes (third and fourth pushbuttons respectively). In the higher ranges (TAP 2 and 3) the output can be increased or decreased in increments or decrements of:
10 amperes (first pushbutton from the left),
1 ampere (second pushbutton from the left),
.1 ampere (third pushbutton from the left), and
.01 ampere (fourth pushbutton from left or first pushbutton on the right). The current output can be stepped as fast as the operator can press, release, and press again: or by pressing and holding in the pushbutton, the output will automatically increment or decrement two digits per second.

When the current channel is in the OFF position,

as the output amplitude is increased, the output tap will be selected automatically. The test set will start in the 3.125A range. As soon as the current amplitude setting increases to 3.126 amperes, the tap will change to 12.5A. Once the current setting exceeds 12.5A amperes, the tap will change to 25A. If the current output is ON, the test set will autorange the output taps only when the waveform begins to distort. After the alarm has sounded for approximately three seconds, the test set will autorange. The output will be interrupted for a very brief time during the tap change operation.

ON/OFF Switch and Lamp

This switch is provided for use in controlling the current output. In the OFF position, the blue output binding post is de-energized, therefore, the current output is OFF regardless of the position of the INITIATE Control Switch. In the ON position, the current output is energized regardless of the position of the INITIATE Control Switch. When the indicating lamp is ON, the output is energized.

INITIATE Switch and Lamp

When the current channel INITIATE Switch is pressed, and the indicating lamp is glowing, the INITIATE Control Switch in the Control Section must be pressed to turn the current output ON and OFF.

Blue and White Current Output Binding Posts

Binding posts for connection of output current. The White binding post is grounded and is used as instantaneous polarity terminal and the Blue binding post is non-polarity.

Three output ranges are provided: 0 to 25 amperes at four volts, 0 to 12.5 amperes at eight volts, and 0 to 3.125 amperes at 32 volts. Each range is capable of delivering its rated current provided the voltage is sufficient to push the current through the impedance of the load. The test set is capable of automatically changing the output taps when it determines that the current output exceeds a given range or if the voltage is insufficient to push the desired test current. As discussed earlier, under the INCREASE and DECREASE pushbutton description, the test set will automatically increase the tap range when the desired test current exceeds a given range. Additionally, the test set will automatically lower the output range (to increase the test voltage) when the impedance of the load exceeds the capabilities of that range to provide sufficient voltage to push the desired output current.

TAP LOCK Switch	To avoid unnecessary auto tap changing during manual operation, i.e. pick-up test between 3.1 to 3.5 amperes, by pressing the TAP LOCK Switch, a given output tap will lock into position and will not autorange.
Error Indication and Alarm	See discussion under Voltage Section.
BACK PANEL	The input line cord, ground terminal, interconnecting plugs, and IEEE-488 BUS connection (optional feature) are mounted on the back of the test set. The following is a description of each item.
Input Cord and Safety Ground	A line cord with a standard three-pronged grounded plug is provided for connection of the test set to a suitable input power source. When using more than one EPOCH-10 test set, it is necessary to connect all units to a suitable input power source using the line cords provided. Additionally, for proper operation of the test system, it is necessary to connect all of the ground terminals on the back panel together. Leads are provided for this purpose.
EPOCH-I/10 INTERCONNECT	When combining more than one EPOCH-I/10 to form a test system, it is necessary to properly interconnect the system using the ribbon connector with plug cable. See details under SELECTION OF MASTER Unit.
IEEE-488 GPIB (Optional) Bus Connection	The optional General Purpose Interface Bus (GPIB) enables the EPOCH-10 to function as a talker-listener with any controller or computer which conforms to the IEEE-488 Bus connector.
EPOCH-II/20 CONTROL and SIGNAL Sockets	See EPOCH-II or EPOCH-20 instruction manuals for connection instructions.

INITIAL SET-UP

Each Model EPOCH-10 is packed separately. Unpack all units and check for any evidence of shipping damage. If visual damage is present, notify freight carrier to make damage claims. Also, notify the factory. The covers are easily removable for access to the front and back panels.

CAUTION

Potentially lethal voltages can be present on the output terminals. It is recommended that the operator thoroughly read the instruction manual and understand the operation of the test set before energizing. An operational check may be performed as follows to verify that the amplitude, phase angle, initiate controls, and monitor circuits are functioning properly.

1. Before plugging in unit(s), make sure the POWER ON/OFF Switch(es) are **OFF.**

2. Plug the line cord for each test set into a suitable source of power, as indicated on the nameplate, and switch the POWER ON/OFF Switch(es) **ON.**

3. It is recommended that all the current and voltage amplitudes and phase angle controls be checked using external instrumentation before placing unit on service.

4. To check the contact monitor tone generator, switch the MONITOR ON/OFF Switch **ON.** Jumper the Green and Black binding posts. The tone signal should sound and the CONTINUITY lamp should glow.

5. To check the 5 to 250V sensing circuitry, simply jumper the Green and Red binding posts. The Green binding post is at 15 volts dc and when the jumper is connected, the tone signal should sound and lamp should glow.

6. Check to insure all outputs are **OFF.** Connect the appropriate instruments to the voltage and current output binding posts. By pressing the INCREASE pushbuttons set a suitable voltage and current output, observe the LED display for amplitude. Press both voltage and current INITIATE Switches, lamps should glow, however, there should be no output yet. Press the INITIATE Control Switch and release, outputs should energize. Press the INITIATE Control Switch again and release, the outputs should de-energize.

7. To verify operation of the external TIMER START circuitry, connect the normally open dry contact start circuitry of an external timer (such as Multi-Amp Models SST-2, EPOCH-IV, EPOCH-V or TV-2) to the TIMER START CONTACTS binding posts. Switch the VOLTAGE/CURRENT Switch to VOLTAGE: VOLTAGE lamp should glow. The voltage channel INITIATE Switch lamp should still be glowing from the test conducted in step 6. If not, press the voltage channel INITIATE Switch, lamp should be glowing now. Press the INITIATE Control Switch and release, the output should be energized, and the external timer should start. Press the INITIATE Control Switch to de-initiate the outputs. Press the VOLTAGE/CURRENT Switch to CURRENT, and repeat the same procedure.

8. Using an oscilloscope, verify that the HARMONIC circuitry is working correctly. Caution should be observed not to ground the current or voltage output through the oscilloscope. The current and voltage White output binding posts are connected to ground. Select the desired harmonic output, either second or third, by pressing the HARMONIC Selector Switch: the indicating lamp which indicates the harmonic, should be glowing. Press the INITIATE Control Switch to initiate the outputs. If oscilloscope is grounded, ground terminal should be connected to the White binding posts.

SELECTION OF MASTER UNIT

Each Model EPOCH-10 incorporates its own dc power supply, phase reference to the line, internal oscillator, and solid-state electronic current and voltage sources. For this reason, each EPOCH-10 test set is self-contained and can be operated independently.

When performing tests which require interconnection of more than one Model EPOCH-I/10 test sets, it is necessary to select one test set as a MASTER Unit so that all outputs have the same phase references for correct phase angle relationship. Additionally, the system is initiated through the MASTER Unit.

Since all Model EPOCH-10 and EPOCH-I test sets use the same syne pulse, any unit can be used as the MASTER Unit.

NOTE: Regarding interconnection and operation of EPOCH-10's with EPOCH-I, both units are interchangeable. Any reference to multiple unit operation of the EPOCH-10 applies to EPOCH-I's.

Incorporated on the back panel of each EPOCH-10 is an interconnecting socket. When a single Model EPOCH-10 is used, no plugs or interconnecting cables are required. A long interconnecting cable with these plugs is provided for making the interconnection when more than one Model EPOCH-10 is used. To make the interconnection, proceed as follows:

1. To conserve work space, each Model EPOCH-10 is designed to stack one on top of another. Although it is not necessary, it is suggested that the operator stack the units together.

2. It is further suggested that the operator use the top unit as the MASTER Unit. This will assist in eliminating confusion when making three-phase, 3 or 4 wire connections to the relay under test.

3. Locate the long interconnecting cable equipped with three plugs. Connect one end of the long three plug cable into the top unit. For units equipped with IEEE-488 GPIB, connect units together using the appropriate GPIB interconnect cable. The connectors are keyed and will only go on one way.

4. When using three test sets, interconnect the middle Model EPOCH-10 unit by plugging the second longest cable into the socket on the middle unit and interconnect the bottom Model EPOCH-10 unit by plugging the longest cable into the socket on the bottom unit. This connection connects each test set to the ac reference in the MASTER Unit. Additionally, all three units must have a common ground connection. To ensure a common ground, connect the ground winged studs on the back panel of each Model EPOCH-10 together with the cables provided.

Plug each unit into a suitable source of input power. The test system is now ready for operation. Failure to make the above interconnection correctly (including ground connections) can result in improper operation of the test system.

To eliminate confusion, it is suggested that the operator set either output on the top Model EPOCH-10 test set, that he wishes to use as the reference, to 0 degrees.

When combining only two (2) Model EPOCH-10 units, simply omit making the connection of the third plug.

Spare interconnecting cables are provided when the test sets are shipped from the factory. If the interconnecting cables are lost, additional cables are available from the factory.

After powering up the interconnected test sets, press the top unit's MASTER/SLAVE Switch. The top unit is now the MASTER, all others should be in the SLAVE mode.

CHANGING GPIB ADDRESS OF EPOCHS

Each EPOCH unit connected to the GPIB must have a unique, non-zero GPIB address. As the EPOCH is turned on, this address is momentarily displayed on the front panel LEDs. If two EPOCH units have the same address, change one of them to a unique address according to the following procedure.

1. Make sure the unit is off.

2. Remove the plate from the back panel by removing the two screws securing the plate.

3. On the plate are one or several connectors, depending on the model. Identify the connector labeled 'IEEE-488 GPIB' and follow the cable from that connector to the PC board inside the unit.

4. Remove this PC board by pulling on the lever to the right. On some models there may be a hard plastic strip covering the lever. If so, you might be able to make the necessary address change without removing the card. If the card must be removed, first remove the strip by unfastening the holding screw.

5. Located on the PC board is a set of dip switches. The switch package is labelled, on the left side, ON with an arrow up. The combination of switch settings determines, in binary, the GPIB address of the unit, with the least significant digit to the left. Each switch in the ON position represents a binary 1, and each switch in the OFF position represents a binary 0. Adjust the switches to a combination that represents a unique, non-zero address < 10. The following binary-to-decimal table for valid addresses is given for reference. Note that the positions of the three switches to the right have no effect on the address.

Decimal	Binary
1	00001
2	00010
3	00011
4	00100
5	00101
6	00110
7	00111
8	01000
9	01001

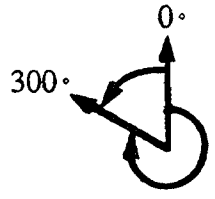
6. Carefully replace the board to its slot. Apply firm pressure until it snaps into position. Replace the plate and fasten with screws.

SETTING PHASE ANGLE RELATIONSHIPS

Think of each EPOCH-10 as a vector generator. Each unit has an internal zero reference to which it references its phase angle settings, as displayed on the LED readouts. This applies to phase angle settings between the voltage and current outputs of one EPOCH-10 or between any combination of voltages and/or currents of two or more units. When setting a phase angle between two sources of one or more EPOCH-10 test sets, it is recommended that one source be set at zero degrees and the other source be referenced to that source at zero degrees. This is for operator convenience and reduces confusion. When setting an angle, the operator has a choice of setting the angle either in the CLOCKWISE or COUNTERCLOCKWISE direction. Pressing the CLOCKWISE pushbuttons increases the phase angle in the clockwise direction from 0.0 to 359.9 degrees. For example, setting an angle of 30 degrees between two sources would vectorially look like . . .

The reference output is 0 degrees and the second source is rotated 30 degrees clockwise or lagging the referenced source by 30 degrees.

Conversely, if the second source were set by pressing the COUNTERCLOCKWISE pushbuttons, the angle decreases in the counterclockwise direction from 359.9 to 0.0 degrees. For example, setting an angle of 300.0 degrees on the second source would vectorially look like . . .



The reference source is 0 degrees, and the second source is rotated to 300 degrees in the counterclockwise direction, which is to say that the second source still lags by 300 degrees or leads the reference source by 60 degrees.

OPERATING PROCEDURES

I. Use of One Model EPOCH-10

After thoroughly reviewing the Theory of Operation Section of this instruction manual, the operator should have a good understanding of the operation of Model EPOCH-10, therefore, no additional information is included in this section for operating only a single test set.

II. Use of Two or More Model EPOCH-10's

This section describes basic operating procedures for using more than one Model EPOCH-10 Test Set for such applications as paralleling current outputs, conducting harmonic restraint tests, paralleling potential sources to provide higher than rated potential, testing over/under voltage relays and forming three phase voltage outputs.

A. Current Sources-Parallel Operation

When the current source voltage available from a single Model EPOCH-10 is insufficient to push higher than rated current from any tap, two or more test sets may be connected in parallel to provide the additional current capacity. To parallel test sets, the sets should first be interconnected following the procedure under SELECTION OF MASTER Unit on page 11. To parallel the test sets, proceed as follows:

1. Using the test lead pairs, connect each current source to relay under test. The parallel connection must be made at the relay *not* at the source in order to assure accuracy of the error detecting circuitry. Note that all current sources White binding posts are grounded.

2. On all test sets, switch the Current Channel ON/OFF Switch to **ON**, or if it is desired to have initiation control of current, press the current channel INITIATE Switch. All parallel current output must be **ON** or be in the **INITIATE** position to prevent internal shunting of current.

3. Each test set amplitude control now operates independently to provide test current. Total output is the sum of the current displayed on the AMPERES amplitude display. To insure optimum system performance, it is recommended that the test current be divided equally between units; i.e. a test current of 35 amperes between two units would be 17.50 on each unit.

4. All currents should be set to the same phase angles.

B. Current Sources-Harmonic Restraint Test

To obtain the current output necessary to conduct harmonic restraint tests on differential relays, two Model EPOCH-10 test sets must be used. One test set will provide either a second or third harmonic current output, while the second unit provides the fundamental "by-pass" current. To set up the two units for harmonic restraint testing, use the following procedure:

1. Parallel the two units using the procedure from PARALLEL OPERATION.

2. Switch the POWER ON/OFF Switch **ON**.

3. Select one of the units to provide the desired harmonic. Switch the HARMONIC Selector Switch to the desired harmonic, second or third.

4. Connect a pair of current output leads from both Model EPOCH-10 test sets to the relay, so that current from each output will be in parallel with one restraint and the operating coil of the relay. Check to insure both commons share the same relay terminal.

5. Press the output INITIATE Switches. The INITIATE Switch Lamps should glow.

6. Increase the output to the appropriate harmonic current. It is recommended that one ampere of harmonic current be set.

7. Initiate outputs by pressing the INITIATE Control Switch. Increase the fundamental current until the relay operates. To calculate the percent of harmonic restraint use the appropriate equation below.

   General Electric BDD

$$\% \text{ of Harmonic Restraint} = \frac{\text{2nd Harmonic Current}}{(\text{Fundamental})^2 + (\text{2nd Harmonic})^2} \times 100$$

   Westinghouse HU

$$\% \text{ of Harmonic Restraint} = \frac{1.2267 \times \text{2nd Harmonic Current}}{(\text{Fundamental})^2 + (\text{2nd Harmonic})^2} \times 100$$

C. Voltage Sources - Outputs Summed Together

Two Model EPOCH-10 test sets may be used to sum voltage outputs to obtain higher than rated voltage provided the load is not grounded. With test sets properly interconnected together, simply connect load between two Red binding posts and set one test set PHASE ANGLE control to 0 degrees and set the other to 180 degrees. The output will now directly add and the amplitude will be the sum of the two amplitudes displayed on the VOLTAGE amplitude displays. Note that the White common terminals are grounded and are not used.

D. Voltage Sources - Dynamic Voltage Relay Test

Over/Under Voltage Relays can be dynamically tested using two Model EPOCH-10 Test Sets and an external timer such as Multi-Amp Models EPOCH-IV, EPOCH-V, TV-2, or SST-2 Solid State Digital Timer. This procedure applies a "normal" voltage to the relay under test and then automatically adjusts the test voltage to a "fault" amplitude either higher for testing over voltage relays or to a lower voltage for testing under voltage relays. Additionally, the external timer is started coincident with "fault" voltage.

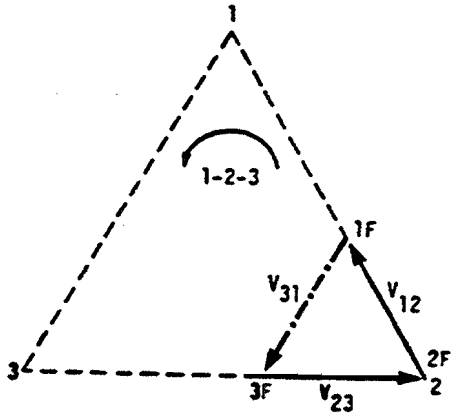
E. Voltage Sources - 30, 3-Wire, Open-Delta and T-Connection

1. Open Delta - Two methods of obtaining three-phase, three-wire voltage source are available. The Open-Delta configuration (shown in Figure 1) is the easier to use when a balanced three-phase source is required because the amplitude and phase

relationship can be set directly. No calculations are necessary. When using the Open-Delta Configuration to set up a phase-to-phase fault, calculations using the Law of Cosines is required to calculate amplitude and phase relationships. (See discussion under T-Connection for simulating unbalanced, phase-to-phase faults without need for calculations.)

For simplicity, when using the Open-Delta configuration, it is suggested the two Model EPOCH-10 units be stacked and the top unit set up as the MASTER Unit. The MASTER Unit's Red output binding post is designated V_1. The SLAVE Red output binding post is designated V_3, while either White COM binding post is designated V_2. With this arrangement, the magnitude and phase angle of the potentials can be easily calculated and set. For the balanced three-phase condition V_{12} and V_{23} are equal in magnitude and separated by an angle of 60°. This is done by setting the MASTER and SLAVE Units potentials equal in magnitude, setting 0 degrees on the MASTER Unit and 300° (60 degrees leading) on the SLAVE Unit (see Figure 1).

FIGURE 1
BALANCED 30 - 3 WIRE FAULT
OPEN DELTA CONNECTION

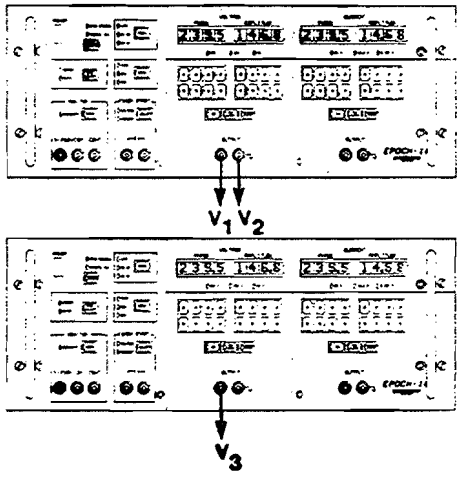


If V_f = Desired Test Potential

Set $V_1 = V_f$ 0°

Set $V_3 = V_f$ 300°

Voltage Output Connections



When setting up an unbalanced Open-Delta configuration, the desired phase-to-phase fault voltage, V_{12} is set using the MASTER Unit and its phase angle is set to 0 degrees. Phase-to-phase voltage V_{23} and its phase angle relationship must then be calculated using the Law of Cosines $V_b^2 = V_a^2 + V_c^2 - 2ac \cos B$. Figure 2 shows the phase relationships and an example of the necessary calculation. For user convenience, the amplitude and phase angle settings for typical V_f fault magnitudes are tabulated.

T-Connection - The second method of obtaining three-phase, three-wire voltage source is the T-Connection. This method as shown in Figure 3 is easier to use when obtaining an unbalanced, phase-to-phase fault simulation because it eliminates calculations. However, three Model EPOCH-10 units are required. To reduce confusion when using the T-Connection, it is suggested that the three Model EPOCH-10 test sets be stacked and the top unit be set up as the MASTER Unit. Then with the MASTER Unit voltage output designated V_a and its phase angle set at 0 degrees: the center Model EPOCH-10 voltage output designated V_b and its phase angle set for 180 degrees: the bottom unit is designated V_c and its phase angle is set for 270 degrees; any combination of balanced 30 or unbalanced 0 - 0 fault conditions can be easily simulated. Figure 3 shows the phase relationships.

NOTE: This method is not good for very low fault voltages, i.e., 5 volts or less, or for testing SKD relays.

F. Voltage Source - 30, 4-Wire, Y-Connection

A three-phase, four-wire potential system can be provided using three Model EPOCH-10 test sets. The vector relationships are shown in Figure 4. This Y-Connection has the advantage of being able to supply higher line-to-line voltage (1.73 x phase-to-neutral voltage) and is ideally suited for simulating phase to ground faults. To eliminate confusion, again, it is suggested the three test sets be stacked and the top unit be used as the MASTER Unit and its voltage source designated as V_a with its phase relationship set for 0 degrees. The center test set is then designated as V_b and phase angle set for 120 degrees. Finally, the lower unit is designated V_c and phase angle set for 240 degrees V_a, V_b and V_c are then connected to the Red potential binding posts on the respective test sets. If a neutral is required, it is connected to a White potential section binding post on any test set to ground the load.

FIGURE 2

UNBALANCED - 0 TO 0 FAULT

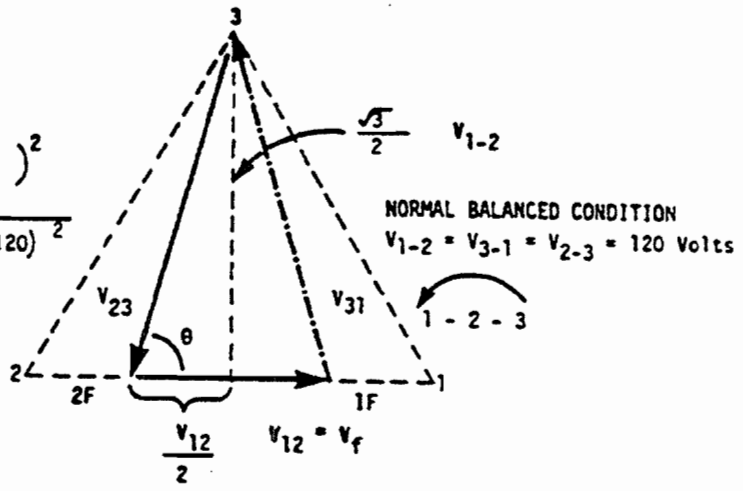
OPEN DELTA CONNECTION

From Law of Cosines

$$V_{23}^2 = \left(\frac{V_{12}}{2}\right)^2 + \left(\frac{\sqrt{3}}{2}\ 120\ \right)^2$$

$$V_{23} = \pm\sqrt{V_{12}^2 + 3\ (120)^2}$$

$$\theta = \text{arc cos}\left(\frac{V_{12}}{2V_{23}}\right)$$

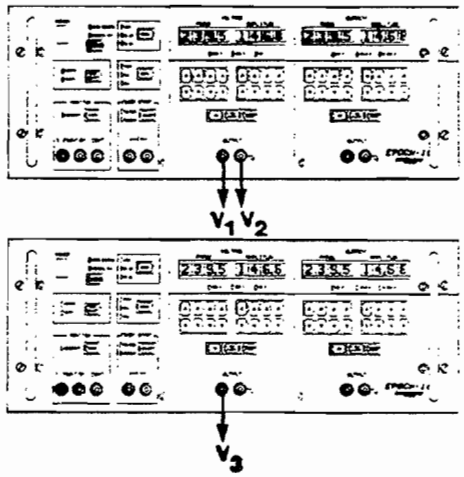


Settings For Typical Fault Voltages

$V_{12} = V_f$

V_{12}	1	5	10	15	20	25	30	35	40	45	50	55	60	65	70
V_{23}	104	104	104	104	104	105	105	105	106	106	106	108	108	109	110
At 0° Lead	270	271	273	274	275	277	278	280	281	282	284	285	286	287	289

Voltage Output Connections

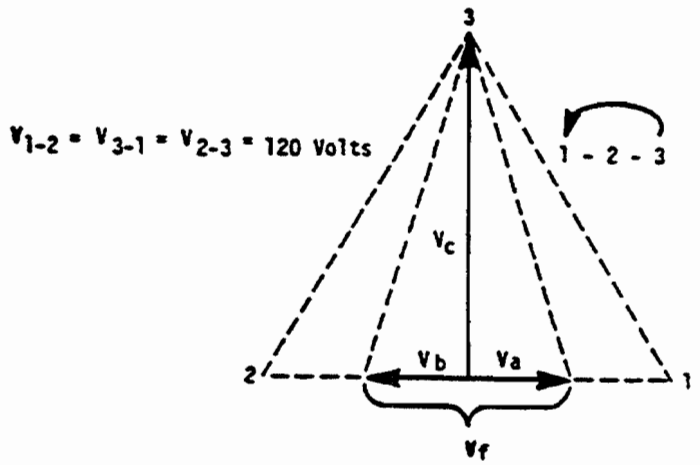


Part № 11983
Rev. 2

FIGURE 3

BALANCED OR UNBALANCED FAULT

T-CONNECTION



V_f = Desired Fault Voltage

V_a = $^1/_2 V_f$ 0°

V_b = $^1/_2 V_f$ 180°

V_c = $\frac{\sqrt{3}}{2}$ 120 or V_c = 104V 270°

Voltage Output Connections

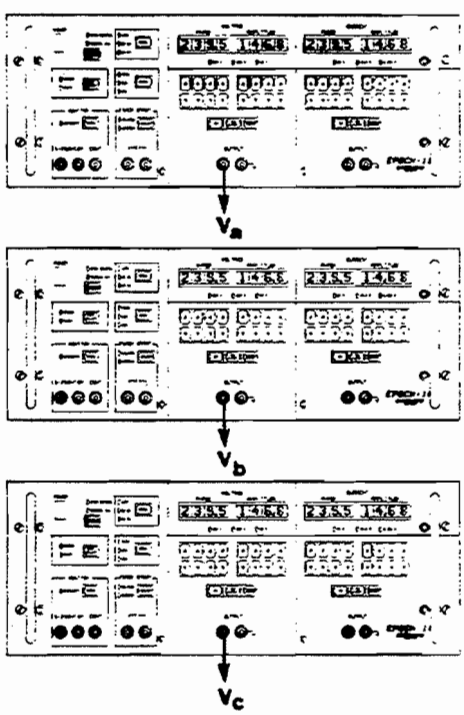
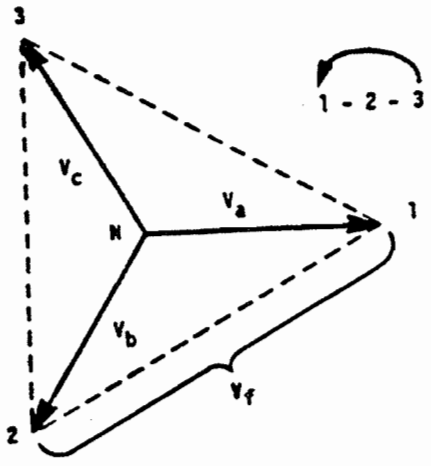


FIGURE 4

BALANCED 3 0

4 WIRE Y CONNECTION



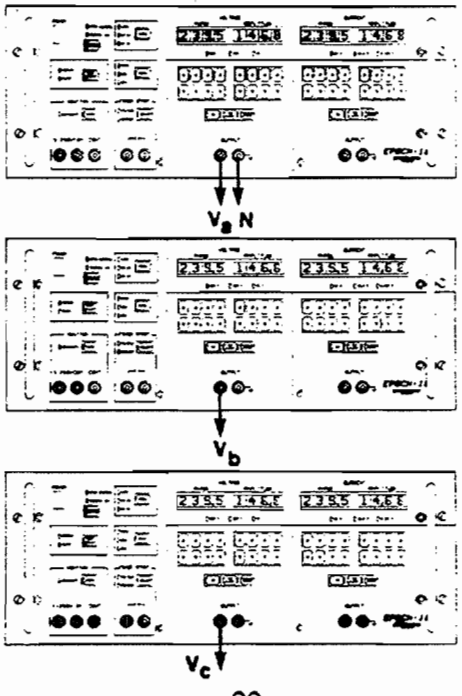
V_f = Desired Fault Voltage

$V_a = \frac{\sqrt{3}}{3} V_f \quad \angle 0°$

$V_b = \frac{\sqrt{3}}{3} V_f \quad \angle 120°$

$V_c = \frac{\sqrt{3}}{3} V_f \quad \angle 240°$

Voltage Output Connections



OUTPUT CAPABILITY

The EPOCH-10's voltage channel is rated at 75VA and current channel is rated at 100VA.

The VA rating of the voltage channel is sufficient for testing today's modern relays, and is unlikely that it will ever be overloaded. The current channel, however, may be overloaded in certain circumstances. Provided the voltage is sufficient to push the current through the impedance of the load circuit, each range is capable of supplying its rated current continuously at ambient room temperature. Each tap may be overloaded by demanding more than its rated voltage or current. This will typically occur when the channel is "TAP LOCKED", and its level is increased beyond the range of that tap. You may continue to overload until waveform distortion results, at which time the distortion alarm will shut the output off. The percent of overload is dependent upon which tap you are using and the load under test. The Time ON, Time OFF will be reduced depending upon the percent of overload or by high ambient temperatures. Should the unit be overloaded for too long or a high ambient temperature persist, a thermal shutdown will occur. When operating both the high current and high voltage taps with very low input voltage, Maximum Power Output capability derating should be considered. In the event of thermal shutdown, leave the unit Power ON, so that the fan can cool down the unit. **Under normal test conditions, the input voltage may vary $\pm$ 10% of 115 volts without effecting the outputs of the unit.** In the event of low input voltage, the current output may be derated under certain conditions. At Maximum Power Output ON the 25 amp tap (tap 3), if the input voltage is - 10% of 115 volts (103.5 volts), at worst case, the output may be derated no lower than 75VA, or 18.75 amperes at 4 volts. The input voltage could drop as low as -5% of 115 volts (109.25 volts) and still maintain Maximum Power Output (100 VA).

TESTING INDUCTION DISK OVERCURRENT RELAYS
Westinghouse Type CO
General Electric Type IAC

The following procedure outlines the most efficient manner to consecutively perform all the listed tests below for an overcurrent relay. This procedure involves the least possible number of changes in connecting test leads and setting controls.

Prior to switching the test set ON, there are no preliminary set-up of controls. Upon the initial powering ON of the test set, all controls automatically reset to zero or OFF conditions.

ALWAYS REFER TO MANUFACTURERS' LITERATURE BEFORE TESTING

TYPES OF TESTS

Zero Check
Pick-up - Induction Unit
Timing - Induction Unit
Pick-up - Instantaneous Unit

ZERO CHECK

This test is usually performed on a new relay to determine that the relay contacts close when the time dial is set to zero. If an "As Found Test" is to be performed on the relay, do not perform zero check steps 3, 4, 5 or 6.

1. Check to insure the POWER ON Switch is **OFF**. Connect the EPOCH-10 test set to a suitable source of power as indicated on the nameplate.

2. Connect a light set of leads from the MONITOR Green and Black binding posts to the trip circuit terminals of the relay induction unit.

3. Turn POWER ON Switch **ON**. POWER ON light should glow.

4. Manually rotate time dial on the relay toward zero until the MONITOR light glows or tone signal sounds. Record reading on the time dial.

5. Adjust for any irregularities and return time dial to specified setting.

6. Turn POWER ON Switch **OFF**.

PICK-UP INDUCTION TEST

This test is to determine the minimum operating current of the relay; that is, the minimum current needed to close the relay contacts for any particular tap settings.

7. Connect induction unit operation coil of relay to the current output binding posts.

8. Turn POWER ON Switch **ON**. Check to insure that the VOLTAGE and CURRENT channel display read zero, if not, set to zero.

9. Press the current channel OUTPUT ON/OFF Switch to turn the current channel **ON**.

10. Increase output until the MONITOR light starts to flicker or the tone signal starts to break.

11. De-energize the current channel by pressing OUTPUT ON/OFF Switch **OFF**.

12. Read and record current from AMPERES display.

TIMING TEST - INDUCTION UNIT

13. Connect start circuit of an external timer to the TIMER START binding posts (refer to TIMER START page 4).

14. Connect relay trip circuit terminals to the stop circuit of the external timer.

NOTE: Depending on the desired value of test current, more than one EPOCH-10 may be required to conduct a timing test. If so, refer to page 13 for parallel operation of two or more Model EPOCH-10's.

15. Connect the current operating coil to the current output binding posts.

16. Set in the desired test current on the AMPERES output display by pressing the appropriate INCREASE pushbuttons.

17. Press the current channel INITIATE Switch, the INITIATE Switch lamp should light. Switch the TIMER START Switch to the CURRENT start position.

18. Reset timer and initiate test set by pressing the INITIATE Control Switch.

19. Test set should initiate and timer start. When the relay trip circuit contacts close, the timer should stop. **Caution: The test set is still initiated. Once relay trips, deinitiate the test set by pressing the INITIATE Control Switch.**

NOTE: If desired, parallel an extra set of leads from the relay contacts to the Green and Black MONITOR binding posts. When the relay trips, it will stop the digital timer and deinitiate the test set.

20. Read and record time on the timer.

21. If it is desired to obtain another point on the curve, repeat steps 18 through 20.

22. When tests are completed, deinitiate test set(s).

TESTING INSTANTANEOUS PICK-UP

Depending on the desired value of test current, more than one EPOCH-10 may be required to conduct an instantaneous test. If so, refer to page 13 for parallel operation of two or more Model EPOCH-10 test sets.

23. Connect the instantaneous unit operating coil of the relay to the current output binding posts.

24. Connect the instantaneous unit trip circuit contacts of the relay to the MONITOR Green and Black binding posts.

25. Set in a value of current that is slightly less than the instantaneous value of the relay.

26. Press the current channel INITIATE Switch to the INITIATE position, lamp should glow.

27. Initiate the current output by pressing the INITIATE Control Switch.

WARNING

Current is flowing through the relay coil until the relay trips or the test set is deinitiated (by pressing the INITIATE Control Switch again).

28. Increase the output until the instantaneous element picks up and the test set deinitiates. A method of initiating and deinitiating at the pick-up point can be used to determine if the pick-up value is true. Slightly increasing or decreasing the current output in association with the initiating and deinitiating of the test set(s) will help to pin point the actual pick-up value. The deinitiating should be simultaneous with the initiating of the output. If not, this indicates a slight time delay, hence just below pick-up. Increase current output until the deinitiating is simultaneous with initiating of the output.

29. Read and record current as indicated on the amperes display.

30. Turn the set OFF.

TESTING UNDER/OVER VOLTAGE RELAYS
Westinghouse Type CV
General Electric Type IAV

GENERAL

The voltage relay is a load balancing relay and is not intended to clear a fault in the power system. In most applications it is used as an undervoltage device and is designed to de-energize the power circuit whenever voltage falls below a predetermined value. Time of operation may be instantaneous or delayed.

The time delay undervoltage relay is also an induction disk relay. The action of the spiral spring is to keep the relay contacts trip circuit closed. The torque produced when voltage is applied to the relay's voltage actuated coil opposes the spring action. Thus, as the applied voltage decreases, the disk rotates to close the relay trip circuit contacts.

The overvoltage relay has the opposite operation. The spring action keeps the relay trip circuit contacts open whenever voltage in the circuit is normal or below normal. A higher than normal voltage produces operating torque on the relay disk.

Prior to switching the test set ON, there are no preliminary set-up of controls. Upon the initial powering up of the test set, all controls automatically reset to zero or off conditions.

ALWAYS REFER TO THE MANUFACTURERS' LITERATURE BEFORE TESTING

TYPES OF TESTS

Pick-up

Timing

PICK-UP TEST

1. Connect the EPOCH-10 test set to a suitable source of power as indicated on the nameplate. Check to insure the POWER ON/OFF Switch is **OFF**.

2. Connect a light set of leads from the MONITOR Green and Black binding posts to the trip circuit contact terminals of the relay induction unit.

3. Connect the relay operating coil to the Red and White potential output binding posts of the Model EPOCH-10.

4. Switch POWER ON/OFF Switch **ON**.

5. Press the voltage OUTPUT ON/OFF Switch to turn the voltage channel **ON**.

6. Increase the voltage output until the MONITOR light begins to flicker or the tone signal begins to break.

7. De-energize the voltage channel by pressing the OUTPUT ON/OFF Switch **OFF**.

8. Read and record pick-up voltage of relay from the VOLTS display.

TIMING TEST

This test requires the use of two Model EPOCH-10's and an external timer.

NOTE: Refer to page 11 on selection of a MASTER Unit and page 14 for explanation of the dynamic voltage relay test.

1. With the two Model EPOCH-10 test sets correctly interconnected, switch the POWER ON/OFF Switches **ON**. Check to insure all outputs are at zero.

2. Connect a set of light leads from the relay potential coils between the two Red voltage output binding posts of the two EPOCH-10 test sets.

3. Select one EPOCH-10 to supply the "normal" test voltage and switch the OUTPUT ON/OFF Switch **ON**.

4. On the second EPOCH-10, press the voltage channel INITIATE Switch to the INITIATE position.

5. Set the desired "normal" voltage on the appropriate test set. The relay under test should assume a normal operating condition.

For an undervoltage relay, follow steps 6 through 12. For an overvoltage relay, go to step 13.

6. Determine what test voltage is to be applied to the relay and set the difference between the "normal" voltage and the "fault" voltage on the second potential output display.

   For example:

115 volts	-	57 volts	= 58 volts
"normal"		"fault"	set on second unit

   When the test system is initiated, the 58 volts from the second unit will subtract from the "normal" voltage, thus the relay will "see" a fault voltage of 57 volts and will start to operate.

7. Connect the yellow TIMER START binding posts to the start circuit of an external timer and switch the TIMER START Switch to VOLTAGE Start position.

8. Connect the stop circuit of the external timer to the relay trip circuit terminals.

   NOTE: The outputs will either add or subtract depending on the phase angle. For subtraction, leave both phase angles at zero. For additive voltages, set either potential to a phase angle of 180°.

9. Reset the external timer and initiate the test set by pressing the MASTER INITIATE Control Switch. The voltages will either add or subtract causing the relay to start to operate. Additionally, the external timer will start.

10. When the external relay trips, the timer will stop. Read and record time.

11. To repeat test, simply press the MASTER INITIATE Control Switch to deinitiate the second voltage channel, allow the relay to reset and reinitiate.

12. After completion of tests, turn both test sets **OFF**.

13. For testing overvoltage relays, first determine what test voltage is to be applied to the relay and set the difference between the "fault" voltage and the "normal" voltage on the second voltage amplitude display. For example:

180 volts	-	120 volts	= 60 volts
"fault"		"normal"	set on second unit

Also, set 180° on the PHASE ANGLE along with the difference between the two voltages. When the test system is initiated, the 60 volts will add to the 120 volts already applied, and the relay will "see" an overvoltage of 180 volts and start to operate. After setting in the 180 degree phase angle and desired overvoltage, complete steps 7 through 12.

PERCENTAGE DIFFERENTIAL RELAYS
Westinghouse Type CA
General Electric Type IJD

GENERAL

This relay compares two similar currents in a circuit, i.e. primary and secondary current of a transformer. Since the relay compares two currents, it is connected to two current transformers. That portion of the circuit between the two CT primaries is referred to as the relay's "zone of protection". The percentage differential relay operates its trip circuit contacts and trip a circuit breaker(s) whenever it senses an abnormal condition within the "zone of protection". The degree of unbalance or abnormality the relay may tolerate is a function of the relay's design. (i.e. 5%, 10%, 25%, or 50% differential)

The simple percentage differential relay has two restraint coils and one operating coil. The operating coil is common to the two restraining coil circuits. Under normal conditions, the currents in the operating coil produce torques that are equal in magnitude but opposite in direction and thus cancel. Under fault conditions, these currents in the operating coil become unequal and produce an operating torque on the disk. When the differential current reaches a predetermined amount, as governed by relay design, the relay trip circuit contacts close.

Prior to switching the test set ON, there are no preliminary set-up of controls. Upon the initial powering ON of the test set, all controls automatically reset to zero or OFF conditions.

ALWAYS REFER TO MANUFACTURERS' LITERATURE BEFORE TESTING

TYPES OF TESTS

1. Connect the Model EPOCH-10 to a suitable source of power. Check to insure the POWER ON/OFF Switch is in the **OFF** position.

2. Connect the operating coil and one restraint coil of the relay to the current output binding post and common.

3. Connect a set of light leads from the MONITOR Green and Black binding posts to the relay trip circuit terminals.

4. Turn POWER ON/OFF Switch **ON**. POWER ON light should glow.

5. Switch the current OUTPUT INITIATE Switch to the INITIATE position.

6. Set in approximate pick-up on current amplitude display.

7. Initiate test set by pressing the INITIATE Control Switch.

8. Increase or decrease current output until the MONITOR light flickers or the tone signal starts to break.

9. Read and record pick-up current. De-energize test set by pressing the INITIATE Control Switch to the **OFF** position.

10. Move the MONITOR leads to the relay terminal for the other fixed contact and

repeats steps 5 through 8.

11. Turn test set **OFF**.

TIMING TEST

12. With the test set connected as described above, turn POWER ON/OFF Switch **ON**. POWER ON light should glow.

13. Connect start circuit of an external timer to the TIMER START binding posts (refer to TIMER START page 4).

14. Connect relay trip circuit terminals to the stop circuit of an external timer.

    NOTE: Depending on the desired value of test current, more than one EPOCH-10 may be required to conduct a timing test. If so, refer to page 13 for instructions on parallel operation of two or more Model EPOCH-10's.

15. Set the desired test current on the current amplitude display.

16. Press the current channel output INITIATE Switch to the INITIATE position. Switch the TIMER START Switch to the current start position.

17. Reset the timer and initiate the test set by pressing the INITIATE Control Switch.

18. When the test set initiates, the timer will start. When the relay trip circuit contacts close, the timer should stop.

    CAUTION: The test set is still initiated. Once the relay trips, deinitiate the test set by pressing the INITIATE Control Switch.

    NOTE: If desired, parallel an extra set of leads from the relay contacts to the Green and Black MONITOR binding posts. When the relay trips, it will stop the digital timer and deinitiate the test set.

19. Read and record trip time.

20. Turn the test set **OFF**.

THROUGH FAULT TEST

21. Turn the test set **ON**. POWER ON light should glow.

22. Connect the restraint coil terminals of the relay to the current output binding posts so that the current flows through the restraint coils in series.

23. Set the desired restraint current on the current amplitude display. Press the current channel INITIATE Switch to the INITIATE position.

24. Initiate test set by pressing the INITIATE Control Switch.

25. Manually turn the relay disc for evidence of restraint.

26. Deinitiate output by pressing the INITIATE Control Switch.

SLOPE TEST

NOTE: Two Model EPOCH-10 test sets are required to conduct the slope test. Refer to pages 13 - 14 and for instructions on operation of two or more EPOCH-10 test sets.

27. Connect the operating coil and one restraint to the output binding posts of one EPOCH-10. Connect the two restraint coil terminals of the relay to the other EPOCH-10 so that current flows through the restraint coils in series. Both commons should share the same terminal. Refer to manufacturers' literature for proper connections of common.

28. Connect a set of light leads from the MONITOR binding posts to the relay trip circuit terminals.

29. Turn POWER ON/OFF Switch **ON**. POWER ON light should glow.

30. Press the current channel INITIATE Switches to the INITIATE position.

31. Initiate the test sets by pressing the MASTER Unit INITIATE Control Switch.

33. Increase or decrease operating current until MONITOR light flickers or tone signal breaks.

34. Deinitiate test set by pressing INITIATE Control Switch.

35. Read and record restraint and operating currents. Calculate slope.

$$\frac{I\ operating}{I\ restraint} \times 100 = \%\ slope$$

36. Turn test sets **OFF** by switching the POWER ON/OFF Switches to the **OFF** position.

TRANSFORMER DIFFERENTIAL RELAY WITH PERCENTAGE AND HARMONIC RESTRAINT
(General Electric Type BDD)

GENERAL

The Type BDD relay is a single-phase transformer differential relay provided with the features of percentage and harmonic restraint and has a sensitive polarized relay as the operating element. Percentage restraint permits accurate distinction between internal and external faults at high currents. Harmonic restraint enables the relay to distinguish, by the difference in waveform, between the differential current caused by an internal fault and that caused by transformer magnetizing inrush. The harmonic restraint and slope tests are written based on testing the relay with all restraint windings set in a 5A tap. If the relay is to be tested with any other tap settings, please refer to the G. E. instruction book under "Periodic Testing". The Type BDD 15 relay is designed to be used for the protection of two-winding power transformers and has two (2) through-current restraint circuits and one (1) differential current circuit. The Type BDD 16 relay is designed to be used with three-winding power transformers and has three (3) through-current restraint circuits and one (1) differential current circuit.

Prior to switching the test set ON, there are no preliminary set-up of controls. Upon the initial powering ON of the test set, all controls automatically reset to zero or off conditions.

ALWAYS REFER TO MANUFACTURERS' LITERATURE BEFORE TESTING

Types of Tests

Pick-up of DHR Unit
Slope (requires two EPOCH-10's)
Harmonic Restraint (requires two EPOCH-10's)
Pick-up of Instantaneous Unit

TESTING PICK-UP

1. Connect the Model EPOCH-10 to a suitable source of power. Check to insure POWER ON/OFF Switch is in the **OFF** position.

2. Connect a set of leads from the current output terminals of the EPOCH-10 to the relay terminals so that the current will energize one restraint coil and the operating coil.

3. Connect an appropriate DC voltage source to the relay terminals across the DHR unit normally open contacts.

4. Turn the test set **ON**. POWER ON light should glow.

5. Adjust dc voltage source until rated dc voltage is applied to the relay.

6. Initiate the test set by pressing the current channel OUTPUT ON/OFF Switch to the **ON** position.

7. Increase current output until the AUX relay picks-up and the relay flag drops. Read and record pick-up. Refer to manufacturers' literature for proper pick-up values.

8. De-initiate test set by pressing the OUTPUT ON/OFF Switch **OFF**. Move lead so that the other restraint coil will be energized. Repeat test.

THROUGH CURRENT RESTRAINT TEST

CAUTION

The relay coils are energized as long as the test set is initiated. Therefore, this test should be conducted as rapidly as possible to prevent damage to the relay coils.

1. Connect the Model EPOCH-10 to a suitable source of power. Check to insure POWER ON/OFF Switch is in the **OFF** position.

2. Connect an appropriate DC voltage source to the relay terminals across the DHR unit normally open contacts.

3. Connect current lead from the Blue current output of the MASTER Unit to the relay terminal number 4 and the common to relay terminal number 6.

4. Adjust dc voltage source until rated dc voltage is applied to the relay.

5. Set a current of 25 Amperes and press the current channel INITIATE Switch to the INITIATE position. Initiate the output by pressing the INITIATE Switch. Relay should be in restraint.

SLOPE TEST

CAUTION

The relay coils are energized as long as the test set is initiated. Therefore, this test should be conducted as rapidly as possible to prevent damage to the relay coils.

1. Since two Model EPOCH-10's are required for this test, refer to pages 13 through 14 for instructions on interconnecting two Model EPOCH-10 test sets.

2. Connect the Model EPOCH-10's to a suitable power source. Check to insure both POWER ON Switches are **OFF**.

3. Connect an appropriate dc voltage source to the relay terminals across the DHR unit normally open contacts.

4. Connect current leads from the MASTER Unit Blue current output terminal and common to the relays terminals 4 and 6 respectively.

5. Connect a set of current leads from the second Model EPOCH-10 to relay terminals 5 and 6. Connect the common terminal to relay terminal 6.

6. Connect a set of light leads from the relay normally open AUX contacts to the Green and Black MONITOR binding posts.

7. Adjust dc voltage source until rated dc voltage is applied to the relay.

8. Turn POWER ON Switch **ON**.

9. Set in 20 amperes on the MASTER Unit current output channel. Press the current channels INITIATE Switches to the INITIATE position.

10. Initiate test sets by pressing the MASTER Unit INITIATE Control Switch to the INITIATE position. Increase the second unit current output until the DHR unit normally open contacts close. Deinitiate test sets by pressing the MASTER Unit INITIATE Control Switch.

11. Read and record current values.

NOTE: For a 25% slope relay set in the 5 amp taps, and 20 amperes applied to the restraint coil, a value of 5.00 amperes would equate to a 25% slope. Refer to manufacturers' literature for allowable tolerances.

HARMONIC RESTRAINT TEST

NOTE: Two (2) Model EPOCH-10 test sets are required for this test. One unit will supply the harmonic, the second unit fundamental current.

1. Refer to page 15 for instructions on harmonic restraint testing before going to the next step.

2. Connect a suitable dc voltage source to the normally open DHR contacts. Adjust the dc voltage source until rated dc voltage is applied to the relay.

3. Connect test sets to the relay per instructions under Harmonic restraint testing. Set in the appropriate harmonic current (1 ampere recommended). Switch the current channels INITIATE Switches to the INITIATE position.

4. Initiate the test system by switching the MASTER INITIATE Control Switch to the INITIATE position. Increase the fundamental current until the relay picks up. Read and record the fundamental and harmonic restraint current. It must be noted that certain BDD relays produce internal RF noise which can cause the EPOCH-10 alarm light to signal a false indication.

NOTE: To determine the percent of harmonic, divide the harmonic restraint current by the sum of the squares of the fundamental current plus harmonic current multiplied by 100.

Example:

$$\frac{\text{1 ampere 2nd harmonic}}{\sqrt{(4.9)^2 + (1)^2}} \times 100 = 20\% \text{ 2nd harmonic}$$

(4.9 amperes fundamental
1 ampere 2nd harmonic)

NOTE: At 1 ampere 2nd harmonic, the relay should operate between 5.19 to 4.65 amperes of fundamental current for a 19 to 21% setting.

5. Turn the test set **OFF**.

INSTANTANEOUS UNIT TEST

NOTE: The instantaneous trip element in the Type BDD relay should have a pick-up value of eight times the tap value. To conduct this test will require at least two (2) Model EPOCH-10 test sets. If the instantaneous trip is set for a value higher than 50 amperes, three EPOCH-10's will be required.

1. Refer to page 13 for Parallel Operation of two or more Model EPOCH-10's.

2. Determine the amount of instantaneous current required and connect the appropriate number of EPOCH-10's to terminals 5 and 6 on the relay. Follow the procedure for parallel operation referenced above.

3. Press the current channel INITIATE Switches to the INITIATE position.

4. Initiate the test set by pressing MASTER Unit INITIATE Control Switch.

5. Increase each output current channel until the relay instantaneous element picks up.

WARNING

Current is flowing through the relay coil until the INITIATE Switch is pressed to the OFF position. Therefore, it is important to conduct this test as rapidly as possible to avoid damage to the relay.

6. As soon as the relay picks up on an instantaneous trip, deinitiate the unit by pressing the INITIATE Control Switch to the **OFF** position. Read and record instantaneous pick-up by adding the current values on the current amplitude displays.

TRANSFORMER DIFFERENTIAL RELAY WITH PERCENTAGE AND HARMONIC RESTRAINT
Westinghouse Type HU and HU-1

GENERAL

The Type HU relay is a single phase high speed transformer differential relay provided with percentage and harmonic restraint element. Percentage restraint permits accurate determination between internal and external faults at high current. Harmonic restraint enables the relay to distinguish between magnetizing inrush current to a transformer and an internal fault. The following tests are based on testing the relay with the restraint taps set in the 5 ampere taps. If the relay is to be tested in any other tap arrangement, refer to the manufacturer's literature for testing instructions.

The Type HU relay has two restraint coils and one operating coil. It is designed to be used for protection of two-winding transformers. The Type HU-1 is designed to protect three winding power transformers. It has three restraint coils and one operating coil.

Prior to switching the test set ON, there are no preliminary set-up of controls. Upon the initial powering ON of the test set, all controls automatically reset to zero or off conditions.

ALWAYS REFER TO MANUFACTURERS' LITERATURE BEFORE TESTING

Types of Tests

Pick-up	Slope (two EPOCH-10's required)
Through Fault	Harmonic Restraint (two EPOCH-10's required)
Timing	Instantaneous Trip

TESTING PICK-UP

1. Connect the Model EPOCH-10 to a suitable source of power. Check to insure the POWER ON/OFF Switch is **OFF**.

2. Connect a set of current leads from the current output terminals of the EPOCH-10 to the relay terminals 5 and 3 so that the current will energize one restraint coil and the operating coil.

3. Connect a set of light leads form the MONITOR Green and Black terminals to the relay trip circuit contacts.

4. Turn the test set **ON**. POWER ON light should glow.

5. Set in a current value that is slightly less than the expected pick-up current on the current amplitude display. Press the current channel INITIATE Switch to the INITIATE position. Block the HRU element closed.

6. Initiate the test set by pressing the INITIATE Control Switch.

7. Increase the current output until the MONITOR light flickers or the tone signal breaks.

8. Deinitiate test set by pressing the INITIATE Control Switch. Read and record pick-up current. Refer to manufacturers' literature for proper pick-up.

9. Repeat test for other restraint coil relay terminals 3 and 7. For HU-1 the pick-up test will have to be done a third time for the extra restraint coil relay terminals 3 and 9.

10. Remove blocking material from HRU element.

THROUGH FAULT TEST

1. With the current channel deinitiated, move the current output leads to terminals number 5 and 7.

2. Set a current that is 50% larger than the pick-up value determined above. Press the current channel INITIATE Switch to the INITIATE position.

3. Initiate the test set by switching the INITIATE Control Switch. The relay should be in restraint.

4. Deinitiate test set by pressing the INITIATE Control Switch.

TIMING TEST

1. Connect start circuit of an external timer, such as Multi-Amp Models EPOCH-IV, EPOCH-V or SST-2, to the TIMER START contacts binding posts (refer to TIMER START page 4).

2. Connect relay trip circuit terminals to the stop circuit of the external timer.

3. Connect a set of current leads from the output binding post to the relay terminals 3 and 7.

4. Set the desired test current on the current channel LED display normally two times the tap value or 10 amperes.

5. Press the current channel INITIATE Switch to the INITIATE position.

6. Switch the TIMER START Switch to the CURRENT Start position.

7. Reset timer and initiate test set by pressing the INITIATE Control Switch.

8. Test set should initiate and timer start. When trip circuit contacts close, timer should stop.

CAUTION

The test set is still initiated. Once relay trips, deinitiate the test set by pressing the INITIATE Control Switch.

9. Read and record time on timer.

DIFFERENTIAL CHARACTER (SLOPE) TEST

CAUTION

The relay coils are energized as long as the test set is initiated. Therefore, this test should be conducted as rapidly as possible to prevent damage to the relay coils.

1. Since two Model EPOCH-10's are required for this test, refer to pages 13 through 14 for instructions on interconnecting two Model EPOCH-10 test sets.

2. Connect the Model EPOCH-10 test sets to a suitable power source. Check to insure both POWER ON Switches are **OFF**.

3. Connect current leads from the MASTER Unit Blue current output binding post and common to relay terminals 5 and 7. Connect the common binding posts to terminal 7.

4. Connect current leads from the second Model EPOCH-10 current output binding post and common to relay terminals 3 and 7 with the common binding post to terminal 7.

5. Connect a pair of light leads from the MONITOR Green and Black binding posts to the relay trip circuit terminals 1 and 10. Block the HRU element closed.

6. Turn POWER ON Switches **ON**.

7. Set a current of 2.0 amperes on the EPOCH-10 that is connected to terminals 3 and 7. Press the SLAVE current channel INITIATE Switch to the INITIATE position.

8. Set a current of 10 amperes on the MASTER Unit EPOCH-10. Press the current channel INITIATE Switch to the INITIATE position.

9. Initiate output of test sets by pressing the MASTER Unit INITIATE Control Switch.

10. Increase the current of the SLAVE EPOCH-10, which is connected to terminals 3 and 7, until the MONITOR light flickers or the tone signal sounds.

11. Deinitiate output by pressing the MASTER Unit INITIATE Control Switch.

12. Read and record the current values. Refer to the Manufacturer's literature for proper pick-up value or slope. For example: a 30% sensitivity should pick-up between 2.8 to 2.95 amperes (Westinghouse I. L. 41-347.ID page 15) with 10 amperes applied to restraint coils.

HARMONIC RESTRAINT TEST

NOTE: Two Model EPOCH-10 test sets are required for this test. One unit will supply the second harmonic current and the other unit will supply the fundamental current.

1. Refer to page 15 for instructions on harmonic restraint testing before going to the next step.

2. Connect the test sets to the relay per instructions under Harmonic Restraint testing on

page 16.

3. Connect a set of light leads to the relay trip circuit from the MONITOR Green and Black binding posts.

4. Set the appropriate harmonic current (1 ampere recommended).

5. Switch the current channel INITIATE Switches to the INITIATE position. Initiate the output by switching the INITIATE Control Switch to the INITIATE position.

6. Increase the fundamental current until the MONITOR light begins to flicker or the tone signal breaks. Read and record the fundamental and harmonic restraint current required to make the HRU element operate.

7. Deinitiate the test system by switching the INITIATE Control Switch.

NOTE: To determine the percent of harmonic, use the formula outlined on page 16.

Example:

$$\frac{1.2267 \times 1}{\sqrt{(8.1)^2 + (1)^2}} \times 100 = 15\% \text{ 2nd harmonic}$$

(8.1 amperes fundamental
1 ampere harmonic)

NOTE: At 1 ampere 2nd harmonic, the relay should operate between 8.7 to 7.6 amperes of fundamental current for a 14 to 16% setting.

INSTANTANEOUS TRIP ELEMENT TEST

NOTE: The instantaneous trip element in the type HU and HU-1 is set at the factory for a pick-up value of 50 amperes (10 x 5A TAPS). To conduct this test will require two (2) Model EPOCH-10 test sets.

1. Refer to page 13 for set up and operating instructions of two or more Model EPOCH-10 test sets in parallel.

2. With the Model EPOCH-10 correctly interconnected, connect the Blue and White binding posts from the two Model EPOCH-10 test sets to relay terminals 3 and 5.

3. Set a current value slightly less than the instantaneous trip value by summation of the two current outputs. Switch the current channel INITIATE Switches to the INITIATE position. Check to insure the current channel phase angles are all set to zero degrees.

4. Initiate the test set by pressing the MASTER Unit INITIATE Switch.

5. Increase the output current until the relay instantaneous element picks up and the relay instantaneous flag drops.

WARNING

Current is flowing through the relay coil until the MASTER Unit INITIATE Switch is switched to the OFF position. Therefore, it is important to conduct this test as rapidly as possible to avoid damage to the relay.

6. As soon as the relays instantaneous element picks-up, deinitiate the unit by pressing the INITIATE Switch to the OFF position. Read and record the instantaneous pick-up by adding the two current values on the current output LED displays.

VOLTAGE CONTROLLED OVERCURRENT RELAY
Westinghouse Type COV

GENERAL

The COV relay contains an induction disc overcurrent unit and an instantaneous undervoltage unit. The undervoltage unit supervises the operation of the overcurrent unit. Regardless of the amount of current passing through the operating coil of the overcurrent unit, no operation takes place unless the undervoltage unit has "dropped out". This means that the overcurrent unit may be set to operate on less than full load current when the voltage falls below a predetermined value. Conversely, the overcurrent unit will not operate as long as the voltage is above the predetermined value.

This relay is normally used to protect a generator against a bus fault.

Prior to switching the test set ON, there are no preliminary set-up of controls. Upon the initial powering ON of the test set, all controls automatically reset to zero or off conditions.

ALWAYS REFER TO MANUFACTURERS' LITERATURE BEFORE TESTING

Pick-up	- undervoltage unit
Drop-out	- undervoltage unit
Voltage	- control of overcurrent unit
Pick-up	- overcurrent unit
Time current characteristics	- overcurrent unit

TESTING PICK-UP AND DROP-OUT OF UNDERVOLTAGE

1. Connect the EPOCH-10 to a suitable source of power as indicated on the nameplate. Check to insure POWER ON Switch is OFF.

2. Connect a set of leads from the Red and White voltage output binding posts to the undervoltage unit operating coil terminals.

3. Connect a set of light leads from the Green and Black MONITOR binding posts to the relay undervoltage unit contact terminals.

4. Turn the POWER ON Switch ON. The POWER ON light should glow.

5. Initiate the voltage output by pressing the OUTPUT ON/OFF Switch to the ON position.

6. Increase the voltage output until the MONITOR light starts to flicker or the tone signal starts to break. Read and record pick-up voltage of the undervoltage unit.

7. Continue to increase until rated voltage is applied to the relay.

8. Slowly decrease the applied voltage until the MONITOR light first glows or tone signal sounds. Read and record drop-out voltage of the undervoltage unit.

9. Press the OUTPUT ON/OFF Switch to the OFF position.

TESTING VOLTAGE CONTROL OF OVERCURRENT RELAY

10. With the test set connected as described above, connect the current output binding posts to the overcurrent operation coil terminals.

    NOTE: Depending on the amount of current required, it may require more than one EPOCH-10 to develope the required test current. If so, refer to page 13 for parallel operation of two or more Model EPOCH-10's.

11. Connect a set of light leads from the Green and Black MONITOR binding posts to the relay trip circuit contact terminals.

12. Press both voltage and current OUTPUT ON/OFF Switches to the ON position.

13. Increase the voltage output until rated voltage is applied to the relay.

14. Increase the current output to approximately four times the tap value of the overcurrent unit. The overcurrent unit should not operate to close the trip circuit contacts.

15. Decrease the voltage output until the undervoltage unit drops out.

16. The overcurrent unit should now operate to close its contacts. MONITOR lamp should glow and/or tone signal should sound.

WARNING

Current is flowing through the relay coil until the OUTPUT ON/OFF Switch is switched to the OFF position. Therefore, it is important to conduct this test as rapidly as possible to avoid damage to the relay.

TESTING PICK-UP AND TIMING OF THE OVERCURRENT UNIT

1. Insure that the undervoltage contacts are closed before conducting tests.

2. Follow the test procedures for testing an overcurrent relay as on pages 22 through 24.

TESTING POWER DIRECTIONAL RELAY
General Electric Type GGP53B

The Type GGP538 relay consists of a time delay overvoltage unit (upper) and a three phase directional unit (lower). The three phase directional unit is an induction-cylinder type element. The overvoltage unit is of the induction-disc construction.

Prior to switching the test set ON, there are no preliminary set-up of controls. Upon the initial powering ON of the test set, all controls automatically reset to zero or off condition.

ALWAYS REFER TO MANUFACTURERS' LITERATURE BEFORE TESTING

Types of Tests

Maximum Torque Angle
Pick-up (Upper Unit)
Timing Test

PICK-UP (UPPER UNIT)

1. Connect the EPOCH-10 to a suitable source of power. Check to insure that the POWER ON Switch is OFF.

2. Connect the voltage output binding posts of the EPOCH-10 to the relay operating coil (see manufacturers' literature).

3. Connect a set of light leads from the relay trip circuit terminals to the MONITOR binding posts.

4. Turn the test set ON. POWER ON light should glow.

5. Press voltage channel INITIATE Switch to the INITIATE position. Initiate the test set by pressing the INITIATE Control Switch.

6. Increase the voltage until the MONITOR light begins to flicker or the tone signal begins to break.

7. Read and record pick-up voltage of the upper unit. For a 120 volt relay the pick-up value should be approximately 57.5 volts. For a 208 relay the pick-up should be approximately 100 volts.

TIMING TEST

1. Connect the EPOCH-10 to a suitable source of power. Insure the POWER ON/OFF Switch is OFF.

2. Connect the relay operating coil (see manufacturer's literature) to the voltage output binding posts.

3. Connect an external timer, such as the Multi-Amp Model EPOCH-V or SST-2, to the TIMER START binding posts. Check to insure the TIMER START Switch is in the voltage position.

4. Turn the test set ON. Reset external timer to zero.

5. Set normal operating voltage on the VOLTAGE channel LED display.

6. Press the voltage channel INITIATE Switch to INITIATE position.

7. Initiate test set by pressing the INITIATE Control Switch.

8. When the relay trip circuit contacts make, the timer will stop. Record time indicated.

9. Turn the test set OFF.

MAXIMUM GGP TORQUE ANGLE

1. Connect the Model EPOCH-10 to a suitable source of power. Check to insure the POWER ON Switch is OFF.

2. Connect a set of leads from the voltage output binding posts of the EPOCH-10 to the relay voltage coils connected in parallel. Observe manufacturers' literature.

3. Connect a set of current leads from the current output binding posts to the relay current coils connected in series. Observe polarities, see manufacturers' literature.

4. Connect a set of leads from the MONITOR Green and Black binding posts to the relay trip circuit terminals.

5. Turn the test set ON by pressing the POWER ON Switch ON.

6. Set rated voltage and current on the LED displays. Also set the phase angle at zero.

7. Press the voltage and current channel INITIATE Switches to the INITIATE position.

8. Initiate the test set by pressing the INITIATE Control Switch.

9. Adjust the phase angle of the current channel until the MONITOR light starts to flicker or the tone signal starts to break. Read and record first angle of pick-up. Angle should be approximately 120°.

10. Continue to rotate the phase angle of the current output until the MONITOR light starts to flicker or the tone signal starts to break. Read and record second angle of pick-up.

11. The relay angle of maximum torque is the middle of the arc through which the relay trip contacts were closed as determined in steps 9 and 10. Maximum torque should be approximately 30°.

12. Turn the test set OFF

TESTING MHO DISTANCE RELAY
General Electric Type GCY 12A

GENERAL

All mechanical maintenance and adjustments should be performed prior to electrical tests. Follow recommended procedures as outlined in the manufacturer's instruction bulletin (except when "as found" tests are required).

Prior to switching the test set ON, there are no preliminary set-up of controls. Upon the initial powering ON of the test set, all controls automatically reset to zero of off conditions.

REFER TO MANUFACTURERS' LITERATURE BEFORE TESTING

Types of Tests

Reach Test - Zones 1, 2, and 3
Maximum Angle of Torque - Zones 1, 2, and 3
Offset

REACH AND MAXIMUM ANGLE OF TORQUE OF M-1 UNIT

1. Connect the voltage output terminals of the EPOCH-10 to relay terminals 20 and 17. Jumper relay terminals 17 to 19 and 18 to 20. Other types of GCY relays may require other connections: refer to manufacturers' literature for placement of voltage leads and polarities.

2. Connect the current output terminals of the EPOCH-10 to the relay current operating coil terminals 10 and 3. Jumpers must be used to series the current through the current coils. For the GCY 12A, place jumpers between relay terminals 4 to 5, 6 to 7 and 8 to 9.

3. Connect a set of light leads to monitor the operation of the M-1 unit trip circuit contacts to the MONITOR Green and Black binding posts.

4. Turn POWER ON.

5. Set desired phase angle for current and voltage for reach test. Set the voltage channel to zero degrees and set the current channel to maximum angle of torque (i.e. 60°) CLOCKWISE.

6. Set the test current to desired value. The value of current will be calculated from the impedance settings of the relay, if unknown use 5 amperes.

7. Press voltage and current channel INITIATE Switches to the INITIATE position. Initiate output by pressing INITIATE Control Switch.

8. Increase the voltage output until the MONITOR lamp is extinguished or tone generator breaks. Continue to increase voltage 10 to 15 volts above this point and then decrease voltage until MONITOR lamp just lights or tone signal sounds. Record voltage, current, and phase angle to determine reach.

NOTE: To determine maximum angle of torque, there are two methods which can be used. One method is to adjust the phase angle equidistance either side of the maximum angle of torque (i.e. $\pm$ 30 degrees) and repeat the procedure used to determine reach. The two points should be equal, if the maximum angle of torque is correct. This procedure is the most expedient when using a mechanical phase shifter, however, since the EPOCH-10 uses regulated voltage and current sources, the following procedure is easier and just as accurate.

9. Reduce voltage output, used to determine reach, by 20%.

10. Increase phase angle by pressing the CLOCKWISE pushbuttons until the MONITOR light begins to flicker or the tone breaks. Record that angle as 0_1. Decrease the phase angle by pressing the COUNTERCLOCKWISE pushbuttons until the MONITOR light begins to flicker or the tone breaks. Record this angle as 0_2. The maximum angle of torque 0_{MAX} is,

$$0_{MAX} = \frac{0_1 + 0_2}{2}$$

11. Deinitiate the test set by pressing the INITIATE Control Switch.

TESTING M-2 UNIT

1. Reconnect MONITOR leads to monitor M-2 unit trip contacts.
2. Repeat steps 1 through 11 of testing M-1 unit.

TESTING M-3 UNIT

1. Reconnect MONITOR leads to monitor M-3 unit trip circuit contacts.
2. Repeat steps 1 through 11 of testing M-1 unit.

OFFSET

1. To determine offset, connect the MONITOR leads to monitor the appropriate unit. Repeat steps 1 through 11 of testing M-1 unit, except set the phase angle to the maximum angle of torque plus 180 degrees (i.e. 60 + 180 + 240 degrees). The voltage will vary from very small to sizable depending upon the offset.

TESTING MHO DISTANCE RELAY
General Electric Type CEY 15

GENERAL

All mechanical maintenance and adjustments should be made prior to the electrical tests. Follow the recommended procedures and relay connections as outlined in the manufacturer's literature, (except when an "as found" test is required).

Prior to switching the test set ON, there are no preliminary set-up of controls. Upon the initial powering ON of the test set, all controls automatically reset to zero or off conditions.

REFER TO MANUFACTURERS' LITERATURE BEFORE TESTING

Types of Tests

Reach Test
Maximum Angle of Torque
Offset

REACH, MAXIMUM ANGLE OF TORQUE AND OFFSET TEST FOR 0 1-2 MHO UNIT

1. Connect voltage output terminals of the EPOCH-10 to the relay potential coil terminals with a set of light leads, observe polarities. Refer to the manufacturer's literature for placement of potential leads and jumpers.

2. Connect the current output terminals of the Model EPOCH-10 to the desired relay current operating coil terminals. Jumpers must be used in order to series the current through the current coils. Refer to the manufacturer's literature for placement of current leads and jumpers.

3. Connect a set of light leads to monitor the operation of the 0 1-2 unit trip circuit contacts to the MONITOR Green and Black binding posts.

4. Turn power ON.

5. Set desired phase angle for current and voltage for reach test. Set the voltage channel to zero degrees and set the current channel to maximum angle of torque (i.e. 60°) CLOCKWISE.

6. Set the test current to desired value. The value of current will be calculated from the impedance settings of the relay, if unknown use 5 amperes.

7. Press voltage and current channel INITIATE Switches to the INITIATE position. Initiate output by pressing INITIATE Control Switch.

8. Increase the voltage output until the MONITOR lamp is extinguished or tone generator breaks. Continue to increase voltage 10 to 15 volts above this point and then decrease voltage until MONITOR lamp just lights or tone signal sounds. Record voltage, current, and phase angle to determine reach.

NOTE: To determine maximum angle of torque, there are two methods which can be used. One method is to adjust the phase angle equidistance either side of the maximum angle of torque (i.e. $\pm$ 30 degrees) and repeat the procedure used to determine reach. The two points should be equal, if the maximum angle of torque is correct. This procedure is the most expedient when regulated voltage and current sources, the following procedure is easier and just as accurate.

9. Reduce voltage output used to determine reach by 20%.

10. Increase phase angle by pressing the CLOCKWISE pushbuttons until the MONITOR light begins to flicker or the tone breaks. Record that angle as 0_1. Decrease the phase angle by pressing the COUNTERCLOCKWISE pushbuttons until the MONITOR light begins to flicker or the tone breaks. Record this angle as 0_2. The maximum angle of torque 0_{MAX} is,

$$0_{MAX} = \frac{0_1 + 0_2}{2}$$

11. Deinitiate the test set by pressing the INITIATE Control Switch.

TESTING 0 2 - 3 UNIT

1. Reconnect MONITOR leads to monitor 0 2-3 unit trip circuit contacts.

2. Repeat steps 1 through 11 of testing 0 1-2 unit.

TESTING 0 3-1 UNIT

1. Reconnect MONITOR leads to monitor 0 3-1 unit trip circuit contacts.
2. Repeat steps 1 through 11 of testing 0 1-2 unit.

OFFSET

1. To determine offset, connect the MONITOR leads to monitor the appropriate unit. Repeat steps 1 through 11 of testing 0 1-2 unit, except set the phase angle to the maximum angle of torque plus 180 degree. (i.e. 60 + 180 = 240 degrees). The voltage will vary from very small to sizable depending upon the offset.

TESTING OF OFFSET MHO BLOCKING RELAY
General Electric Type CEB 16B

GENERAL

All mechanical maintenance and adjustments should be performed prior to electrical tests. Follow recommended procedures as outlined in the manufacturer's instruction bulletin (except when "as found" tests are required).

Prior to switching the test set ON, there are no preliminary set-up of controls. Upon the initial powering ON of the test set, all controls automatically reset to zero or off conditions.

REFER TO MANUFACTURERS' LITERATURE BEFORE TESTING

Types of Tests

Reach Test - Zones 1, 2, and 3
Maximum Angle of Torque
Offset

REACH, MAXIMUM ANGLE OF TORQUE AND OFFSET TESTS

1. Connect voltage output terminals of the EPOCH-10 to the relay potential coil terminals with a set of light leads, observe polarities. Refer to manufacturers' literature for placement of potential leads and polarities.

2. Connect the current output terminals of the EPOCH-10 to the desired relay current operating coil terminals. Jumpers must be used in order to series the current through the current coils. For placement of current leads and jumpers, refer to the table given in the manufacturer's literature.

3. Connect a set of light leads to monitor the operation of the MB unit trip circuit contacts to the MONITOR Green and Black binding posts.

4. Turn POWER ON.

5. Dial in desired phase angle (lag or lead), current and voltage for reach test.

6. Press INITIATE Switches for both voltage and current. Initiate output by pressing INITIATE Control Switch.

7. Increase voltage until the MONITOR lamp/tone generator begins to flicker or tone breaks. Record voltage, current and phase angle to calculate reach.

8. Increase the voltage output until the MONITOR lamp is extinguished or tone generator breaks. Continue to increase voltage 10 to 15 volts above this point and then decrease voltage until MONITOR lamp just lights or tone signal sounds. Record voltage, current, and phase angle to determine reach.

   NOTE: To determine maximum angle of torque, there are two methods which can be used. One method is to adjust the phase angle equidistance either side of the maximum angle or torque (i.e. $\pm$ 30 degrees) and repeat the procedure used to determine reach. The two points should be equal, if the maximum angle of torque is correct. This procedure is

the most expedient when using a mechanical phase shifter, however, since the EPOCH-10 uses regulated voltage and current sources, the following procedure is easier and just as accurate.

9. Reduce voltage output, used to determine reach by 20%.

10. Increase phase angle by pressing the CLOCKWISE pushbuttons until the MONITOR light begins to flicker or the tone breaks. Record that angle as 0_1. Decrease the phase angle by pressing the COUNTERCLOCKWISE pushbuttons until the MONITOR light begins to flicker or the tone breaks. Record this angle as 0_2. The maximum angle of torque 0_{MAX} is,

$$0_{MAX} = \frac{0_1 + 0_2}{2}$$

11. Deinitiate the test set by pressing the INITIATE Control Switch.

TESTING 0 2-3 UNIT

1. Reconnect MONITOR leads to monitor 0 2-3 unit trip circuit contacts.

2. Repeat steps 1 through 11 of testing 0 1-2 unit.

TESTING 0 3-1 UNIT

1. Reconnect MONITOR leads to monitor 0 3-1 unit trip circuit contacts.

2. Repeat steps 1 through 11 of testing 0 1-2 unit.

OFFSET

1. To determine offset, connect the MONITOR leads to monitor the appropriate unit. Repeat steps 1 through 11 of testing 0 1-2 unit, except set the phase angle to the maximum angle of torque plus 180 degree (i.e. 60 + 180 + 240 degrees). The voltage will vary from very small to sizeable depending upon the offset.

COMPENSATOR DISTANCE RELAY
Westinghouse Type KD

Refer to the manufacturer's instruction literature for values of current, voltage and phase angles applicable to the relay under test, as these values will change with relay reach and model.

EQUIPMENT REQUIRED

(2) Model EPOCH-10 Relay Test Sets

Types of Tests

3-0 Unit Minimum Pick-Up (Reach) Test
0-0 Unit Minimum Pick-Up (Reach) Test
Phase 1-2
Phase 2-3
Phase 3-1

Angle of Maximum Torque

3-0 Unit (Lower Unit)
0-0 Unit (Upper Unit)
Phase 1-2
Phase 2-3

Prior to switching the test set ON, there are no preliminary set-up of controls. Upon the initial powering ON of the test set, all controls automatically reset to zero of OFF conditions.

ALWAYS REFER TO MANUFACTURERS' LITERATURE BEFORE TESTING

CALCULATION OF TEST VALUES OF CURRENT FOR RELAY TAP SETTINGS - 30 UNIT REACH TEST

$$Z_R = \frac{T \quad S}{1 + M} \text{ Ohms}$$

Where:
T = Compensator Tap Value
S = Autotransformer primary tap value
$\pm M$ = Autotransformer secondary tap value.

This value is a per unit value. The sign is positive when "L" is above "R" and negative when "R" is above "L".

The impedance measured by the 30 unit is equal to

$$Z_R = \frac{V_{L\text{-}L}}{1.73 \quad I_L}$$

With the phase angle set at the maximum torque angle.

$$I_{test}\ 30 = \frac{V_{L-L}}{1.73\ Z_R}$$

Test current for other than nominal torque angle sitting should be

$$I_0 = \frac{I_{test}\ 30\ \text{Sin}\ 0\ \text{max}}{\text{Sin}\ B}$$

Example:

$T = 6.1\ M = +0.15$
$S = 1\ V_L\text{-}L = 30$ volts

$$Z_R = \frac{6.1 \times 1}{1 + 0.15}$$

$Z_R = 5.30$ Ohms

$$I_{test}30 = \frac{30 \text{ volts}}{1.73 \times 5.30 \text{ Ohms}}$$

Test current required to operate 30 unit under the above conditions, tap settings and phase angle are

$I^{test}30 = 3.27$ amperes minimum

Manufacturer's tolerance is + 5%.

To calculate test current for other than nominal torque angle,

$0_{max} = 75°$ (old maximum torque angle)
$B = 60°$ (new maximum angle of torque)
$I_{test}30 = 3.27$ amperes
$I_0 =$ New test current

$$I_0 = \frac{3.27 \text{ Sin } 75°}{\text{Sin } 60°} = 3.64 \text{ amperes}$$

Preliminary Relay Connections

1. Jumper relay terminal 12 to 19

2. Jumper relay terminals 14, 16, and 18 together

NOTE: The terminals will remain jumpered throughout all tests.

30 MINIMUM PICK-UP (REACH) TEST

1. Refer to page 11 for Selection of MASTER Unit. Also refer to page 14 for operation of a 30, Open-Delta potential source.

2. With the two Model EPOCH-10 relay test sets correctly interconnected, connect them to a suitable source of power as indicated on the nameplate data. Turn Power ON.

3. Connect a set of light leads from the MASTER Unit voltage output binding posts to relay terminals 7 and 8. Connect the Red 150 V binding posts to terminal 7 and the common to terminal 8.

4. Connect one light lead from the Red150 V binding post on the second EPOCH-10 to relay terminal 9.

5. Connect a set of current leads from the appropriate MASTER Unit current output binding post and common to relay terminals 13 and 18 respectively.

6. Connect a set of light leads from the MONITOR Green and Black binding posts to the appropriate terminals on the relay to observe operation of the 30 unit contacts, (normally terminals 10 and 20).

7. Switch the voltage and current channel INITIATE Switches of the selected outputs to the INITIATE position.

8. Set a value of 30 volts and a zero degree phase angle on the Master Unit voltage output display. Set a voltage of 30 volts at an angle of 300 degrees on the Slave or second model EPOCH-10.

9. Set a current value slightly less than the calculated value on the current display at an angle of 105 degrees (75 degree maximum angle of torque).

10. Initiate the test system by pressing the MASTER Unit INITIATE Control Switch.

11. Increase the current output until the MONITOR light begins to flicker and/or the tone signal starts to break.

12. Read and record the pick-up current value. Deinitiate test system by pressing the MASTER Unit INITIATE Control Switch.

ANGLE OF MAXIMUM TORQUE, 30 UNIT

1. Set up connections to the relay the same as for 30 Minimum Pick-Up (Reach) Test.

2. Switch POWER ON Switch to the ON position.

3. Set current to a value 50% higher than calculated minimum pick-up for 30 unit.

4. Switch voltage and current channel switches to the INITIATE position.

5. Initiate the output by pressing the MASTER Unit INITIATE Control Switch.

6. Rotate the current output phase angle to find angles 0_1 and 0_2 by increasing and decreasing the value of the phase angle on the current channel display. When the MONITOR light flickers or the tone signal breaks, read and record angles.

7. Deinitiate output by pressing the MASTER Unit INITIATE Control Switch.

NOTE: To determine the maximum angle of torque, 0 max, for the 30 unit, use the following formula:

$$0_{max} = \frac{0_1 + 0_2}{2} - 30 \text{ degrees}$$

Example: $0_1 = 53$ degrees
$0_2 = 157$ degrees

$$0_{max} = \frac{53 + 157}{2} - 30 \text{ degrees} = 75°$$

CALCULATION OF TEST CURRENT FOR 0 - 0 UNIT

$$Z = \frac{TS}{1 \pm M} = \text{Ohms}$$

T, S, and M have same values for 30 unit as described earlier.

$$I_{test}\ (0 - 0) = \frac{V_{L-L}}{2Z}$$

Example:

V_{L-L} - 30 volts

$$Z = \frac{6.1 \times 1}{1 + 0.15} = 5.30 \text{ Ohms}$$

$$I_{test}\ (0 - 0) = \frac{30 \text{ volts}}{2(5.30 \text{ Ohms})} = 2.83 \text{ Amps}$$

The minimum current required to operate the 0 - 0 unit under the above conditions is 2.83 amperes minimum + 5%.

0 - 0 MINIMUM PICK-UP (REACH) TESTS
PHASE 1-2

1. Repeat steps 1 through 4 for the 3 0 Minimum Pick-Up (Reach) Test.

2. Connect a set of current leads from the appropriate MASTER Unit current output binding post and common to relay terminals 13 and 15 respectively.

3. Connect a set of light leads from the MONITOR Green and Black binding posts to the appropriate terminals on the relay to observe operation of the 0 - 0 unit contacts, (normally terminals 10 and 11).

4. Switch the voltage and current channel switches of the selected outputs to the INITIATE position.

5. Set a value of 30V at a phase angle of zero degrees on the MASTER Unit. The voltage for V_b and associated phase angle must be calculated, (see page 18 Voltage Sources - 3 0, 3-wire Open-Delta). For a voltage V_{12} = 30 V, the calculated voltage V_{23} = 105 volts at a phase angle of 278 degrees. Set 105 volts at 278 degrees. Set 105 volts at 278 degrees on the second Model EPOCH-10. For other voltages and phase angles see Figure 2, page 18.

6. Set a current value slightly less than the calculated value on the current output display, at a phase angle of 75 degrees.

7. Initiate the test system by pressing the MASTER Unit INITIATE Control Switch.

8. Increase the current output until the MONITOR light begins to flicker and/or the tone signal starts to break.

9. Read and record the pick-up current value. Deinitiate test system by pressing the MASTER Unit Control Switch to the OFF position.

ANGLE OF MAXIMUM TORQUE, 0 - 0 UNIT
Phase 1-2

1. Set up of controls and connections to the relay the same as for Phase 1-2 Minimum Pick-Up (Reach) Test, steps 1 through 5.

2. Connect a set of light leads from the MONITOR Green and Black binding posts to appropriate terminals on the relay to observe operation of the 0 - 0 unit contacts, (normally terminals 10 and 11).

3. Set a current value of 150% of minimum current calculated to operate the 0 - 0 unit contacts.

4. Initiate output of test system by pressing the MASTER Unit INITIATE Control Switch.

5. Rotate the current output phase angle to find angles 0_1 and 0_2 by increasing and decreasing the value of the phase angle on the LED display. When the MONITOR light flickers or the tone signal breaks, read and record angles.

6. Deinitiate output by pressing the MASTER Unit INITIATE Control Switch to the OFF position.

NOTE: To determine the maximum angle of torque, 0_{max}, for the 0 - 0 unit (phase 1-2) use the following formula:

$$0_{max} \quad \text{Phase } 1\text{-}2 = \frac{0_1 + 0_2}{2}$$

MINIMUM PICK-UP PHASE 2-3

1. Switch the current channel ON/OFF Switch to the OFF position, and move the current leads to relay terminals 17 and 15 from the appropriate current output binding, with the common to the terminal 17.

2. Move the voltage lead from the MASTER Unit 150V Red binding post from relay terminal 7 to terminal 8. Move the voltage lead from the second EPOCH-10 150V Red binding post from relay terminal 9 to terminal 7. Move the remaining lead to relay terminal 9.

   NOTE: All voltages, current, and phase angle remain the same as calculated in Phase 1-2 reach test.

3. Repeat test procedure for the 0 - 0 Minimum Pick-Up Phase 1-2 test, steps 3 through 9.

ANGLE OF MAXIMUM TORQUE, 0-0 UNIT
Phase 2-3

1. Set up controls and connections to the relay the same as for Phase 2-3 Pick-up (Reach) Test, steps 1 and 2.

   NOTE: All values, current and phase angles remain the same as calculated values for the Phase 1-2 Angle of Maximum Torque Test.

2. Repeat test procedure, steps 3 through 6, for the Angle of Maximum Torque, 0 - 0 Unit Phase 1-2.

MINIMUM PICK-UP PHASE 3-1

1. Switch the current channel ON/OFF Switch to the OFF position. Move the current leads to relay terminals 17 and 13 with the common to relay terminals 13.

2. Move the voltage lead from the MASTER Unit voltage COM binding post from relay terminal 8 to terminal 7. Move the voltage lead from the second EPOCH-10 150V Red binding post from relay terminal 7 to terminal 8. Move the remaining voltage lead to relay terminal 9.

   NOTE: All voltages, current and phase angles remain the same as calculated in the Phase 1-2 reach test.

3. Repeat test procedure for the 0 - 0 Minimum Pick-Up Phase 1-2 Test, steps 3 through 9.

STATIC GROUND DISTANCE RELAY
WESTINGHOUSE TYPE SDG 1, 2, 3, 4

Refer to the manufacturer's instruction literature for values of current, voltage and phase angles applicable to the relay test, as these values will change with relay reach and model.

EQUIPMENT REQUIRED

1. Three (3) Model EPOCH-10 relay test sets
2. One (1) Model TV-2, EPOCH-IV or EPOCH-V Timer
3. One (1) DC Voltmeter

TYPES OF TESTS

1. Reach Distance Unit
   A. Reach Phase A-N (Westinghouse Test #5)
   B. Reach Phase B-N (Westinghouse Test #6)
   C. Reach Phase C-N (Westinghouse Test #7)

2. Maximum Torque Unit
   A. Phase A-N
   B. Phase B-N
   C. Phase C-N

3. Two Phases to Ground Desensitizer Check

   A. Phases A-B
   B. Phases B-C
   C. Phases C-A

4. Operation of Overcurrent Unit

5. D. C. Target and Seal-In

Prior to switching the test set ON, there are no preliminary set-up of controls. Upon the initial powering ON of the test set, all controls automatically reset to zero or off conditions.

ALWAYS REFER TO THE MANUFACTURER'S LITERATURE BEFORE TESTING

CALCULATION OF TEST VALUES OF CURRENT FOR RELAY TAP SETTINGS

Definitions:

T = Compensator Tap Value
S = Autotransformer Tap Value
0 = Maximum Sensitivity Angle
$\pm$M = Autotransformer secondary tap value. This is a per unit value and is determined by the algebraic sum of the values between "L" and "R". Sign is positive when "L" is over "R" and negative when "R" is over "L".

The reach Z_0 varies with the maximum sensitivity angle 0 as follows:

$$Z_0 \text{ TS } (1 \pm M) \quad x \quad \frac{\sin 0}{\sin 75°}$$

The impedance (Z) is also equal to,

$$Z_1 = \frac{3\ V_{L-N}}{(2 + P)\ I_L} \times \frac{\sin 0}{\sin 75°}$$

Where $P = \frac{Z_0}{Z_1}$

with Z_o = Zero Sequence Reach
Z_1 = Positive Sequence Reach

The test current required is equal to,

$$I = \frac{V_{L-N}}{(2 + P)\ Z1}$$

EXAMPLE: .2 -4.25 Ohm Relay

All $T = 1.23$
$T_o = 3.69$
All $S = 1$
All $M = +.18$
$0 = 75°$

Assume test voltage

$$V_{L\text{-}N} = 20 \text{ volts}$$

Ohmic Reaches are as follows:

$$Z_1 = TS\ (1 \pm M) \frac{\sin 0}{\sin 75°}$$

$$Z_1 = 1.23 \times 1\ (1 + .18) \frac{\sin 75°}{\sin 75°}$$

$$Z_1 = 1.46 \text{ ohms}$$

$$Z_o = T_oS(1 + M) \frac{\sin 0}{\sin 75°}$$

$$Z_o = 3.69 \times 1\ (1 + .18) \frac{\sin 75°}{\sin 75°}$$

$$Z_o = 4.35 \text{ ohms}$$

Test Current Required,

$$I = \frac{3\ V_{L-N}}{(2 + P)\ Z_1}$$

$$I = \frac{60}{(2 + 2.97)\ 1.46}$$

The current required to operate the distance unit under the above conditions of tap settings, voltage, and phase angle is,

$$I = 8.27 \text{ amperes}$$

Allowable tolerances (according to Westinghouse I.L. 41-496.5C) is $\pm$ 3.5%.

Preliminary Relay Connections

Connect relay terminals 12 to 14 to 16 to 19 with jumpers. These terminals will remain jumpered throughout all tests.

TESTING DISTANCE UNIT (REACH) A-N WESTINGHOUSE #5

1. Refer to page 11 for Selection of MASTER Unit. Also refer to page 17 for operation of a 30, 4-wire, Y-connection.

2. With the three Model EPOCH-10 relay test sets correctly interconnected, connect them to a suitable power source as indicated on the nameplate data. Turn power ON. Connect TV-2 or EPOCH-IV to a suitable power source and turn power ON.

3. Connect a set of light leads from the TV-2 or EPOCH-IV D.C. Voltage output binding posts to relay terminals 2 and 3 with the + binding post to relay terminal 3.

4. Connect a set of voltage leads from the MASTER EPOCH-10 voltage output binding posts to relay terminals 6 and 7 with the ground post to relay terminal 6.

5. Connect a voltage lead from the second EPOCH-10 Red 300 V output binding post to relay terminal 8.

6. Connect a voltage lead from the third EPOCH-10 Red 300 V output binding post to relay terminal 9.

7. Connect a set of current leads from the MASTER EPOCH-10 current output binding posts, to relay terminals 13 and 18 with the ground binding post to relay terminal 18.

8. Connect a set of light leads from the MONITOR Red and Black binding posts to the appropriate terminals of the relay observe operation of the relay (normally relay terminals 11 and 2, with the Red binding post connected to relay terminal 11).

9. Set the TV-2 or EPOCH-IV output range selector Switch in the 200 volt position. Adjust the TV-2 or EPOCH-IV DC Voltage Output to 125 volts.

10. Switch all voltage channel INITIATE Switches to the INITIATE position. Switch the MASTER Unit current channel to the INITIATE position.

11. Set the MASTER Unit EPOCH-10 voltage channel to the appropriate test voltage (normally 20 volts) at zero degrees. Set current channel to a phase angle of 75 degrees.

12. Set the second EPOCH-10 voltage output to 70 volts at 120 degrees.

13. Set the third EPOCH-10 voltage output 70 volts at 240 degrees.

14. Initiate the test system by pressing the MASTER Unit INITIATE Control Switch.

15. Increase the MASTER Unit EPOCH-10 current output until the MONITOR light begins to flicker and/or the tone signal starts to break. Read and record values of current, voltage, and phase angle where relay operated.

16. Deinitiate output by pressing the MASTER Unit INITIATE Control Switch.

TESTING DISTANT UNIT (REACH) B-N, WESTINGHOUSE TEST #6

Set up of controls and test procedure are the same as for the A-N tests with the following exceptions:

1. Move the current lead from relay terminal 13 to relay terminal 15.

2. Set the B-N voltage at 20 volts and the A-N and C-N voltages at 70 volts.

3. Adjust the phase angle so the current lags the B-N voltage by 75°. The current channel phase angle display should read 195°.

TESTING DISTANCE UNIT (REACH) C-N, WESTINGHOUSE #7

Set-up of controls and test procedures are the same as for the A-N tests with the following exceptions:

1. Move the current lead from relay terminal 15 to relay terminal 17.

2. Set the C-N voltage at 20 volts and the A-N and B-N voltages at 70 volts.

3. Adjust the phase angle so the current lags the C-N voltage by 75°. The current channel phase angle display should read 315°.

TESTING ANGLE OF MAXIMUM TORQUE PHASE A-N, WESTINGHOUSE TEST #5

NOTE: This test is complicated for the SDG, SDG-1, and SDG-2 relays by the presence of a transient blocking circuit, and the two-phase-to-ground fault desensitizer circuit. To disable the two-phase-to-ground desensitizer for the SDG-1, -2, and -5 relays, connect a 10K resistor between terminals #10 to #1 on the large printed circuit board (for SDG between terminals #10 and #4). To disable the transient blocking circuit, short out resistor R48 on the same board.

1. Set-up of controls and connections to the relay the same as "Testing Distance Unit (Reach) A-N" (see steps 1 through 14).

2. Set a current value of 130% of the required current to operate the distance unit at the maximum angle of torque, the MONITOR light should be ON.

3. Slowly increase the current output phase angle, by pressing the CLOCKWISE pushbuttons, until the relay resets. Then, decrease the phase angle back towards 75 degrees until the relay is fully tripped. Note the angle as 0_1. Continue to decrease the phase angle towards zero degrees by pressing the COUNTERCLOCKWISE pushbuttons, until the relay again resets. Then increase the phase angle until the relay is full tripped. Note the angle 0_2. The maximum angle of torque is:

$$0_{max} \quad A\text{-}N = \frac{0_1 + 0_2}{2}$$

4. Deinitiate output by pressing the MASTER Unit INITIATE Control Switch.

TESTING ANGLE OF MAXIMUM TORQUE PHASE B-N, WESTINGHOUSE TEST #6

Use the same test connections as for the B-N reach test (Westinghouse for Test #6). Set the test potentials $V_{C\text{-}N}$ = 20 volts, $V_{A\text{-}N}$ = 70 volts. Follow the same procedure as for Phase A-N Maximum Angle of Torque, except start the phase angle at 195° instead of 75°.

TESTING ANGLE OF MAXIMUM TORQUE PHASE C-N, WESTINGHOUSE TEST #7

Use the same test connections as for the C-N reach test (Westinghouse for Test #7). Set the test potentials $V_{C\text{-}N}$ = 20 volts, $V_{A\text{-}N} = V_{B\text{-}N}$ = 70 volts. Follow the same procedure as for Phase A-N Maximum Angle of Torque, except start the phase angle at 315° instead of 75°.

NOTICE: After conducting the Maximum Angle of Torque Tests, REMOVE ALL JUMPERS AND 10k TEST RESISTOR FROM THE LARGE PRINTED CIRCUIT BOARD.

TESTING TWO-PHASE-TO-GROUND DESENSITIZER A-B COMBINATION

1. Use the same test connections as for the A-N Distance Unit (Reach) Test (see Steps 1 through 9), except no AC current connections are required for this test (step 7).
2. Switch all voltage channel INITIATE Switches to the INITIATE position.
3. Set the MASTER Unit EPOCH-10 voltage channel ($V_{A\text{-}N}$) to 10 volts at 0 degrees.
4. Set the second EPOCH-10 voltage channel ($V_{B\text{-}N}$) to 10 volts at 120 degrees.
5. Set the third EPOCH-10 voltage channel ($V_{C\text{-}N}$) to 70 volts at 240 degrees.
6. Initiate the output of the test system by pressing the MASTER Unit INITIATE Control Switch.
7. Check the DC voltage on the small printed circuit board located just behind R1-R4 potentiometers terminal "10" (positive) located behind R1 and relay terminal "2". It should measure between 11.5 to 20 vdc.
8. Reset voltages $V_{A\text{-}N}$ and $V_{B\text{-}N}$ to 70 volts. The DC voltage should have disappeared.

TESTING TWO-PHASE-TO-GROUND DESENSITIZER B-C COMBINATION

1. Use the same procedure as for the A-B combination, except set voltages as follows:

   Step 3: Set $V_{A\text{-}N}$ (MASTER Unit) = 70 volts

   Step 5: Set $V_{C\text{-}N}$ = 10 volts

   Step 8: Reset voltages $V_{B\text{-}N}$ and $V_{C\text{-}N}$ to 70 volts.

TESTING TWO-PHASE-TO-GROUND DESENSITIZER A-C COMBINATION

1. Use the same procedure as for the A-B combination, except set voltages as follows:

   Step 3: Set $V_{A\text{-}N}$ (MASTER Unit) = 10 volts

   Step 4: Set $V_{B\text{-}N}$ = 70 volts

   Step 5: Set $V_{C\text{-}N}$ = 10 volts

   Step 8: Reset voltages $V_{A\text{-}N}$ and $V_{C\text{-}N}$ to 70 volts.

TESTING OVERCURRENT UNIT

1. Set-up controls and test connections as for the A-N Distance Unit (Reach Test), see steps 1 through 14 except set MASTER Unit voltage as follows:

   Step 11: Set $V_{A\text{-}N}$ (MASTER Unit) = 0 volts

2. Slowly increase the MASTER Unit output current until the MONITOR light begins to flicker or the tone signal starts to break. For the 0.2 to 4.35 Ohm relay, the relay should operate at 0.75 to 0.83 amperes. For the 1 to 31 Ohm relay, it should operate at 0.37 to 0.42 amperes.

3. Record pick-up of overcurrent unit. Deinitiate output by pressing the MASTER Unit INITIATE Control Switch.

D.C. TARGET TEST (SDG only)

Only Model TV-2 or EPOCH-IV required for this test.

1. Connect a pair of current leads from the TV-2 or EPOCH-IV D.C. current output binding posts to relay terminals 1 and 11.

2. Block the SDG contacts closed.

3. Set TV-2 or EPOCH-IV output range switch in 2 Amp position. Turn TV-2 or EPOCH-IV Power Switch ON.

4. Slowly increase D.C. current output until relay target drops

5. Read and record current displayed.

6. Return output control to zero and switch power ON/OFF Switch OFF.

7. Remove blocking material from relay contacts.

SYNCHRONOUS CHECK RELAYS
GENERAL ELECTRIC TYPE IJS52D

Equipment required

2 EA. Model EPOCH-10 Relay Test Sets
1 EA. Model TV-2, EPOCH-IV, EPOCH-V or SST-2 Digital Timer Unit

Types of Tests

1. Pick-up of Induction Disk

2. Timing of Induction Disk

ALWAYS REFER TO THE MANUFACTURER'S LITERATURE BEFORE TESTING

Prior to switching the test set ON, there are no preliminary set-up of controls. Upon the initial powering ON of the test set, all controls automatically reset to zero or off conditions.

TESTING PICK-UP OF INDUCTION DISK

1. Refer to page 11 for Selection of MASTER Unit.

2. With the two EPOCH-10 relay test sets correctly interconnected, connect them to a suitable source of power as indicated on the nameplate data. Turn Power ON.

3. Connect a pair of test leads from the MONITOR Green and Black binding posts to the trip circuit contact terminals of the relay induction unit.

4. Connect a pair of voltage leads from the MASTER EPOCH-10 voltage output binding posts to one of the relay potential coil terminals. Observe polarities (i.e. terminals 7 and 8 with the ground to 8).

5. Connect a pair of voltage leads from the SLAVE EPOCH-10 voltage output binding posts to the other relay potential coil terminals. Observe polarities (i.e. terminals 5 and 6 with the ground to 6).

6. Set the MASTER and SLAVE EPOCH-10 voltage outputs to the rated voltage of the relay potential coils at zero degrees.

7. Press the MASTER and SALVE EPOCH-10 Voltage Output ON/OFF Switches to ON. The relay contacts should close and the MONITOR lamp should glow.

8. Begin to slowly increase the phase angle of the MASTER EPOCH-10 by pressing the CLOCKWISE pushbutton of the Voltage Channel. When the MONITOR lamp begins to flicker or the tone breaks, record this phase angle. (i.e. 20 degrees).

9. Reset the phase angle back to zero and begin to slowly decrease the phase angle of the MASTER EPOCH-10 by pressing the COUNTERCLOCKWISE pushbuttons. When the MONITOR lamp begins to flicker or the tone breaks, record the phase angle (i.e. 340 degrees).

10. Turn the output OFF by pressing the OUTPUT ON/OFF Switches to the OFF positions.

TIMING OF INDUCTION DISK

1. Repeat steps 1, 2, 4, 5, and 6 of TESTING PICK-UP OF INDUCTION DISK.

2. Connect a pair of test leads from the MASTER EPOCH-10 TIMER START binding posts to the start circuit of the external timer unit (such as the Multi-Amp Models TV-2, EPOCH-IV, EPOCH-V, or SST-2) and switch the TIMER START circuit to the voltage start position.

3. Connect a pair of test leads from the trip circuit contact terminals of the relay induction unit to the stop circuit of the external timer.

4. Switch the voltage channel output INITIATE Switches to the INITIATE position.

5. Check to insure that both voltage channels are set at rated voltage and zero degrees. Reset the external timer.

6. Initiate the test system by pressing the MASTER INITIATE Control Switch. The voltage will be applied to the relay and the timer will start.

7. When the relay contacts close, the timer will strop. Read and record the closing time.

8. Turn the outputs OFF by pressing the MASTER INITIATE Control Switch to the deinitiate position.

TESTING DIRECTIONAL GROUND DISTANCE RELAY
GENERAL ELECTRIC TYPE GCXG-51

GENERAL

The GCXG-51 relay is a high speed three-zone directional ground distance relay. The first and second zones of protection are provided by Ohm Units while, the third zone starting unit is the Mho type.

The Ohm Unit is an induction cup unit with both current and voltage coils acting like a single-phase induction motor.

The Mho Unit is similar to the Ohm Unit with exception that the design allows the armature to rotate in either direction depending on the value of voltage, current and phase angle. There are certain phase angle relationships where the Mho Unit will not operate, therefore, the Mho Unit has a directional characteristic.

REFER TO THE MANUFACTURER'S LITERATURE BEFORE TESTING

Equipment Required

2 EA. EPOCH-10's

1 EA. TV-2 or EPOCH-IV

Types of Tests

Reach Test - Zone 1, 2, and 3
Maximum Angle of Torque
Testing OX Relay

GCXG

Testing OHM Unit (Zone 1), Reach and Maximum Angle of Torque

1. Connect the Red Potential output binding post of the EPOCH-10 to relay terminal 17 and the ground to relay terminal 18.

2. The relay has two sets of current coils. Place a jumper between relay terminals 6 and 7 so the test current will flow through these sets of coils in series. Connect the current output binding post to relay terminals 5 and 8, the ground to relay terminal 8.

3. Connect a set of light leads from the MONITOR Green and Black binding posts to the appropriate relay terminals to observe the operation of the OHM Unit contacts (Zone 1).

4. Turn POWER ON.

5. Set the voltage channel to zero degrees and set the current channel to 90 degrees by pressing the CLOCKWISE pushbuttons.

6. Set the test current to desired value. The value of the current will be calculated from the impedance settings of the relay.

7. Press voltage and current channel INITIATE Switches to the INITIATE position. Initiate output by pressing INITIATE Control Switch.

8. Increase the voltage output until the MONITOR lamp is extinguished or tone generator breaks. Continue to increase voltage 10 to 15 volts above this point and then decrease voltage until MONITOR lamp just lights or tone signal sounds. Record voltage, current and phase angle to determine reach.

   NOTE: To determine maximum angle of torque, there are two methods which can be used. One method is to adjust the phase angle equidistance either side of the maximum angle of torque (i.e. $\pm$ 30 degrees) and repeat the procedure used to determine reach. The two points should be equal, if the maximum angle of torque is correct. This procedure is the most expedient when using a mechanical phase shifter, however, since the EPOCH-10 uses regulated voltage and current sources, the following procedure is easier and just as accurate.

9. Reduce voltage output used to determine reach by 20%.

10. Increase phase angle by pressing the CLOCKWISE pushbuttons until the MONITOR light begins to flicker or the tone breaks. Record that angle as 0_1. Decrease the phase angle by pressing the COUNTERCLOCKWISE pushbuttons until the MONITOR light begins to flicker or the tone breaks. Record this angle as 0_2.

$$0_{MAX} = \frac{0_1 + 0_2}{2}$$

11. Deinitiate the test set by pressing the INITIATE Control Switch.

Testing Ohm Unit (Zone 2), Reach and Maximum Angle of Torque

1. Leave the existing connections to the relay as they are (see steps1 and 2 under Testing OHM Unit (Zone 1). Move the MONITOR leads to observe the closure of the OHM Unit and OX Unit, normally open contacts.

2. Close the OX relay contacts by blocking its armature in the closed position (this relay is normally mounted behind the nameplate).

3. Repeat steps 4 through 11 for Testing OHM Unit Zone 1.

4. Remove blocking from OX Unit of the relay.

Testing Starting Unit (Zone 3), Reach and Maximum Angle of Torque

NOTE: This test requires two EPOCH-10 test sets.

1. Leave the existing connections to the relay as they are (see step 1 and 2 under Testing OHM Units Zone 1. Move the MONITOR leads to observe the closure of the starting unit contacts.

2. Turn POWER ON.

3. Connect the second EPOCH-10 SLAVE Unit, Red potential output binding post to relay terminal 19 and ground to relay terminal 20.

4. On the MASTER current channel, set an angle of 60° and desired test current. For short reach, it may require two current sources in parallel.

5. Set MASTER Unit voltage channel to zero degrees and zero volts. Set SLAVE Unit voltage channel to 90 degrees at 120 volts.

   NOTE: Since the current is lagging the MASTER potential by 60°, by lagging the polarizing voltage by 90° this will give the desired result of the current leading the polarizing voltage by 30°.

6. Press voltage and current channel INITIATE Switches to the INITIATE position. Initiate output by pressing MASTER INITIATE Control Switch.

7. Increase the voltage output of the MASTER Unit until the MONITOR lamp is extinguished or tone signal sounds. Record voltage, current, and phase angle to determine reach.

   NOTE: To determine maximum angle of torque, there are two methods which can be used. One method is to adjust the phase angle equidistance either side of the maximum angle of torque (i.e. $\pm$ 30 degrees) and repeat the procedure used to determine reach. The two points should be equal, if the maximum angle of torque is correct. This procedure is the most expedient when using a mechanical phase shifter, however, since the EPOCH-10 uses regulated voltage and current sources, the following procedure is easier and just as accurate.

8. Reduce voltage output, used to determine reach by 20%.

9. Increase phase angle by pressing the CLOCKWISE pushbuttons until the MONITOR light begins to flicker or the tone breaks. Record that angle as 0_1. Decrease the phase angle by pressing the COUNTERCLOCKWISE pushbuttons until the MONITOR light begins to flicker or the tone breaks. Record this angle as 0_2.

   The maximum angle or torque 0_{MAX} is,

$$0_{MAX} = \frac{0_1 + 0_2}{2}$$

10. Deinitiate the test set by pressing the INITIATE Control Switch.

Testing OX Unit

1. Block OHM Unit trip circuit contacts closed (top unit).

2. Connect a pair of light leads from the D. C. VOLTAGE OUTPUT on TV-2 or EPOCH-IV to relay terminals which will energize the OX Unit coil.

3. Connect a pair of light leads from the OX Unit normally closed contacts to the Green and Black binding posts on the EPOCH-10.

4. Turn POWER ON Switches ON. TV-2 or EPOCH-IV, and EPOCH-10. The MONITOR lamp should glow or tone generator sound.

5. Switch the DC Voltage ON/OFF Switch to the ON position and increase the DC output until the MONITOR lamp flickers or tone breaks. Observe the DC voltage and record the pick-up voltage of the OX relay.

6. Return the DC output to zero.

7. Reconnect the leads from the MONITOR terminals to the normally open contacts of the OX Unit. The MONITOR lamp should be extinguished.

8. Increase the DC output until the MONITOR lamp flickers or tone generator sounds. Observe the pick-up voltage of the OX relay.

9. Increase the DC output until the MONITOR lamp glows without flickering, then slowly decrease the DC output until the MONITOR lamp is extinguished. Observe the dropout voltage of the OX relay on the digital voltmeter.

10. Return the DC to zero and turn OFF both the EPOCH-10 and the TV-2 or EPOCH-IV.

HIGH SPEED PHASE AND GROUND DISTANCE RELAY
ASEA TYPE RAZFE

This test procedure is for performing an acceptance test on the ASEA RAZFE relay. For details concerning these tests, consult ASEA Receiving Acceptance Bulletin UUS/RF 1087. For additional information regarding the operation of the relay, consult ASEA Application Guide 61-12AG.

EQUIPMENT REQUIRED

1. Three (3) Model EPOCH-10 relay test sets

2. One (1) Model TV-2 or EPOCH-IV Timer/Voltage-Auxiliary Unit

TYPES OF TESTS

1. Zone 1 Reach Test

   A. REACH PHASE A - N, L1, B1 Characteristics
   B. REACH PHASE B - N, L1, B1 Characteristics
   C. REACH PHASE C - N, L1, B1 Characteristics

2. Zone 2 Reach Test

   A. REACH PHASE A - N, L2, B1 Characteristics
   B. REACH PHASE B - N, L2, B1 Characteristics
   C. REACH PHASE C - N, L2, B1 Characteristics

3. Zone 3 Reach Test

   A. REACH PHASE A - N, L3, B1 Characteristics
   B. REACH PHASE B - N, L3, B1 Characteristics
   C. REACH PHASE C - N, L3, B1 Characteristics

4. Zone 1 Two Phase Test

   A. PHASE B - C Check, ZK1, C1 Characteristics

5. Zone 2 Two Phase Test

   A. PHASE B - C Check, ZK2, C2 Characteristics

6. Zone 3 Two Phase Test

   A. PHASE B - C Check, ZK3, C3 Characteristics

7. Three-Phase Test

8. Zone 2 Timer Test

9. Zone 3 Timer Test

Preliminary Relay Settings

a = 4 K_n = 1.0
b = 4 T_n = 18 ms
c = 0.5 T_k = 18 ms

	P_1	P_2	P_3
A(R)	100	50	25
B(S)	100	50	25
C(T)	100	50	25

Tables I-XII show expected values for a relay rated 5A. If your relay has a 2A rating, multiply the recorded value by 2.5 and compare with the values in Tables I-XII.

Preliminary Relay Connections

Connect jumpers between TH-4 to 6 to 8 to 10 on the test side of the test plug (see Figure A).

Connect EPOCH-10's to the test plug as shown in Figure A.

Jumper TH-1 to TH-2 on the test side of the test plug. This will allow the observation of a START target in conjunction with the TRIP target.

Upon the initial powering ON of the test set, all controls automatically reset to zero or OFF conditions.

ALWAYS REFER TO THE MANUFACTURER'S LITERATURE BEFORE TESTING

Zone 1 Reach Test: A - N

1. Refer to page 11 for Selection of MASTER Unit. Also refer to page 17 for operation of a 30, 4-wire, Y-connection.

2. With the three Model EPOCH-10 relay test sets correctly interconnected, connect them to a suitable power source as indicated on the nameplate data. Turn power ON. Connect TV-2 or EPOCH-IV to a suitable power source and turn power ON.

3. Connect a set of light leads from the TV-2 or EPOCH-IV D.C. Voltage output binding posts to relay test plug TH-1 and TH-18 with the + binding post to TH-1. Test connections to the TV-2 or EPOCH-IV 125 volt DC supply are required only if the RAZFE is to be tested as a separate unit outside of the protective relay panel. Since the RAZFE is part of a protective relay scheme, DC has already been supplied to the TH-1 (+125 VDC) and TH-18 (-125 VDC) via the station battery. To ensure personal safety, make sure that the lug ends of TH-1 and TH-18, which extend from the test handle, are well insulated.

4. Remove Zone 2 and Zone 3 timers (TK2 and TK3).

5. Set the TV-2 or EPOCH-IV output range selector switch in the 200 or 125 volt position. Adjust the TV-2 or EPOCH-IV DC Voltage Output to 125 volts.

6. Switch all voltage channel INITIATE Switches to the INITIATE position.

7. Set the MASTER Unit current channel to 4 amperes and to the INITIATE position.

8. Set the MASTER Unit EPOCH-10 voltage channel to the appropriate test voltage (normally 5 volts) at zero degrees. Set current channel to a phase angle of 82 degrees.

9. Set the second EPOCH-10 voltage output to 67 volts at 120 degrees.

10. Set the third EPOCH-10 voltage output to 67 volts at 240 degrees.

11. Initiate the test system by pressing the MASTER Unit INITIATE Control Switch.

12. Increase the MASTER Unit EPOCH-10 current output "R1" until the MONITOR light begins to flicker and/or the tone signal starts to break. Read and record values of current, voltage, and phase angle where relay operated. See Table I for L1 and B1 characteristics for minimum and maximum current levels.

13. Deinitiate output by pressing the MASTER Unit INITIATE Control Switch.

14. Repeat steps 7 through 12 for current channel phase angles of 60, 30, 15, 10, and 0 degrees. See Table 1 for minimum and maximum current levels.

NOTE: Correct sequence of target operation for L1 characteristic is RN shows before U. Correct sequence of target operation for B1 characteristic is RN and U show simultaneously.

TABLE I

ZONE 1 REACH TEST GROUND FAULT CHARACTERISTIC, A-N (L_1, B_1 CHARACTERISTICS)

	ANGLE (0) (Degrees)	Z LOOP (Ohms)	V TEST (V_F) (Volts)	I TEST (I) (Amps) (Min - Max)
	82	.485	5	9.79 - 10.82
L_1	60	.530	5	8.96 - 9.91
	30	.824	5	5.76 - 6.37
	15	.860	5	5.23 - 6.4
	10	.833	5	5.4 - 6.6
B_1	0	.8	5	5.63 - 6.88

ZONE 1 REACH TEST, B-N

Set up of controls and test procedure are the same as for the A-N tests with the following exceptions:

1. Set the B-N test voltage "SU" to 5 volts and the A-N test voltage to 67 volts.

2. Adjust the phase angle of B phase current channel so the current lags the B-N voltage by 82 degree (set angle to 120° + 82° = 202°). Switch B phase current channel to INITIATE position.

3. Reset A phase current channel to zero.

4. Repeat the procedure for A-N test, see Table II for L_1 and B_1 characteristics for min. and max. current levels.

NOTE: Observe SN and U targets for correct operation.

TABLE II

ZONE 1 REACH TEST GROUND FAULT CHARACTERISTIC, B-N (L_1, B_1 CHARACTERISTICS)

	ANGLE (0) (Degrees)	Z LOOP (Ohms)	V TEST (V_F) (Volts)	I TEST (I) (Amps) (Min - Max)
	202	.485	5	9.79 - 10.82
L_1	180	.530	5	8.96 - 9.91
	150	.824	5	5.76 - 6.37
	135	.860	5	5.23 - 6.4
	130	.833	5	5.4 - 6.6
B_1	120	.8	5	5.63 - 6.88

ZONE 1 REACH TEST, C-N

Set-up of controls and test procedures are the same as for the A-N tests with the following exceptions:

1. Set the C-N test voltage "TU" to 5 volts and the B-N test voltage to 67 volts.

2. Adjust the phase angle of C phase current channel so the current lags the C-N voltage by 82° (set angle to 240° + 82° = 322°).

3. Reset B phase current channel to zero.

4. Repeat the procedure for A-N test, see Table III for L_1 and B_1 characteristics for min. and max. current levels.

NOTE: Observe TN and U targets for correct operation.

TABLE III

ZONE 2 REACH TEST GROUND FAULT CHARACTERISTIC, A-N (L_2, B_1 CHARACTERISTICS)

	ANGLE (0) (Degrees)	Z LOOP (Ohms)	V TEST (V_F) (Volts)	I TEST (I) (Amps) (Min - Max)
	322	.485	5	9.79 - 10.82
L_1	300	.530	5	8.96 - 9.91
	270	.824	5	5.76 - 6.37
	255	.860	5	5.23 - 6.4
	250	.833	5	5.4 - 6.6
B_1	240	.8	5	5.63 - 6.88

ZONE 2 REACH TEST, A-N

Replace TK2 (zone 2 timer) and set on lowest setting. Leave TK3 (Zone 3 timer) removed.

Set up of controls and test procedure are the same as for the A-N zone 1 tests with the following exceptions:

1. Set the A-N test voltage to 10 volts.

2. Repeat Zone 1 Reach test A-N. See Table IV for L_2 and B_1, min. and max. current levels and phase angles).

   NOTE: Correct sequence of target operation for L_2 characteristic is RN shows before U. Correct sequence of target operation for B_1 is RN and U show simultaneously. Overall observed targets should be:

   RN, TK2 and U.

TABLE IV

ZONE 2 REACH TEST GROUND FAULT CHARACTERISTIC, A-N (L_2, B_1 CHARACTERISTICS)

	ANGLE (0) (Degrees)	Z LOOP (Ohms)	V TEST (V_F) (Volts)	I TEST (I) (Amps) (Min - Max)
	82	.97	10	9.59 - 11.03
L_2	60	1.06	10	8.77 - 10.1
	45	1.25	10	7.44 - 8.56
	30	1.01	10	8.91 - 10.9
B_2	20	.89	10	10.1 - 12.36

ZONE 2 REACH TEST, B-N

Set up of controls and test procedure are the same as for the Zone 1 Reach test, B-N.

1. Set the B-N test voltage to 10 volts.

2. Repeat the procedure for the B-N ZONE 2 REACH TEST. See Table V for L_2 and B_1, min. and max. current levels and phase angle.

   NOTE: Correct sequence of target operation is SN before U for L_2 operation. For B1, SN and U show simultaneously. Overall observed targets should be:

   RN, TK_2 and U.

TABLE V

ZONE 2 REACH TEST GROUND FAULT CHARACTERISTIC, B-N (L_2, B_1 CHARACTERISTICS)

	ANGLE (0) (Degrees)	Z LOOP (Ohms)	V TEST (V_F) (Volts)	I TEST (I) (Amps) (Min - Max)
	202	.97	10	9.59 - 11.03
L_2	180	1.06	10	8.77 - 10.1
	165	1.25	10	7.44 - 8.56
	150	1.01	10	8.91 - 10.9
B_2	140	.89	10	10.1 - 12.36

ZONE 2 REACH TEST, C-N

Set up of controls and test procedure are the same as for the Zone 1 Reach test, C-N.

1. Set the C-N test voltage to 10 volts.

2. Repeat the procedure for the C-N ZONE REACH TEST. See Table VI for L_2 and B_1, min. and max. current levels and phase angles.

   NOTE: Correct sequence of target operation is TN before U for L_2 operation. For B_1, TN and U show simultaneously. Overall observed targets should be:

   TN, TK_2 and U.

TABLE VI

ZONE 2 REACH TEST GROUND FAULT CHARACTERISTIC, C-N

(L_2, B_1 CHARACTERISTICS)

	ANGLE (0) (Degrees)	Z LOOP (Ohms)	V TEST (V_F) (Volts)	I TEST (I) (Amps) (Min - Max)
	322	.97	10	9.59 - 11.03
L_2	300	1.06	10	8.77 - 10.1
	285	1.25	10	7.44 - 8.56
	270	1.01	10	8.91 - 10.9
B_1	260	.89	10	10.1 - 12.36

ZONE 3 REACH TEST, A-N

Replace TK_3 (Zone 3 timer) and set on lowest setting.

Set up of controls and test procedure are the same as for the A-N Zone 2 tests.

1. Repeat the Zone 2 A-N REACH TEST. See Table VII for L_3 Characteristic is RN shows before U. Correct sequence of target operation for B1 is RN and U show simultaneously. Overall observed targets should be:

   RN, TK_2, TK_3 and U.

TABLE VII

ZONE 3 REACH TEST GROUND FAULT CHARACTERISTIC, A-N (L_3, B_1 CHARACTERISTICS)

	ANGLE (0) (Degrees)	Z LOOP (Ohms)	V TEST (V_F) (Volts)	I TEST (I) (Amps) (Min - Max)
	82	1.94	10	4.64 - 5.67
L_3	75	1.96	10	4.59 - 5.61
	60	2.12	10	4.25 - 5.19
	50	1.49	10	6.04 - 7.38
B_1	40	1.18	10	7.63 - 9.32

ZONE 3 REACH TEST, B-N

Set up of controls and test procedure are the same as for the B-N Zone 2 Test.

1. Repeat the ZONE 2, B-N REACH TEST. See Table VII for L_3 and B_1 min. and max. current levels and phase angles.

   NOTE: Correct sequence of target operation is SN before U for L_3. For B_1, SN and U show simultaneously. Overall observed targets should be:

   SN, Tk_2, TK_3, and U.

TABLE VIII

ZONE 3 REACH TEST GROUND FAULT CHARACTERISTIC, B-N (L_3, B_1 CHARACTERISTICS)

	ANGLE (0) (Degrees)	Z LOOP (Ohms)	V TEST (V_F) (Volts)	I TEST (I) (Amps) (Min - Max)
	202	1.94	10	4.64 - 5.67
L_3	195	1.96	10	4.59 - 5.61
	180	2.12	10	4.25 - 5.19
	170	1.49	10	6.04 - 7.38
B_1	160	1.18	10	7.63 - 9.32

ZONE 3 REACH TEST, C-N

Set up of controls and test procedure are the same as for the C-N Zone 2 test.

1. Repeat the ZONE 2, C-N REACH TEST. See Table X for L_3. For B_1, TN and U show simultaneously. Overall observed targets should be:

   TN, TK2, TK3, and U.

TABLE IX

ZONE 3 REACH TEST GROUND FAULT CHARACTERISTIC, C-N (L_3, B^1 HARACTERISTICS)

	ANGLE (0) (Degrees)	Z LOOP (Ohms)	V TEST (V_F) (Volts)	I TEST (I) (Amps) (Min - Max)
	322	1.94	10	4.64 - 5.67
L_3	315	1.96	10	4.59 - 5.61
	300	2.12	10	4.25 - 5.19
	290	1.49	10	6.04 - 7.38
B_1	280	1.18	10	7.63 - 9.32

ZONE 1 TWO PHASE TEST

Since the phase-to-phase logic is based on a polyphase relay operating characteristic, only a pair of phase-to-phase test qualities need be used to verify the integrity of the phase-to-phase unit. B to C phase-phase voltages will be used for this test.

1. Connections to relay remain the same as phase-neutral tests. Repeat steps 1 through 7 of ZONE 1 REACH TEST, A-N, except connect MASTER Unit current channel across B and C phase relay terminals 3 and 5.

2. With the test system properly connected to the relay, set the test voltages and phase angles as follows;

   $V_A(R_U)$ = 8.66 volts @ 0°

   $V_B(S_U)$ = 5 volts @ 150°

   $V_C(T_U)$ = 5 volts @ 210°

   Set MASTER Unit (A0) current channel to 180 degrees.

3. Initiate the test system by pressing the MASTER Unit INITIATE Control Switch.

4. Increase the MASTER Unit current output until the MONITOR light begins to flicker and/or the tone signal starts to break. Read and record value of current where relay operated. See Table X for min. and max. current levels.

5. Deinitiate output by pressing the MASTER Unit INITIATE Control Switch.

6. Repeat steps 4 and 5 for current channel phase angles of 172, 150, 0, and 330 degrees. See Table X for min. and max. current levels.

7. Verify correct phase-to-phase (B-C) operation by observing the 20 and U target operation.

TABLE X

ZONE 1 REACH TEST GROUND FAULT CHARACTERISTIC, A-N

(ZK_1, C_1) CHARACTERISTICS V_F=5V

Z LOOP (Ohms)	I TEST (Angle)	I TEST (I) (Amps) (Min - Max)
0.48	180°	9.9 - 10.94
0.484	172°	9.82 - 10.86
0.450	150°	10.56 - 11.68
----	0°	Verify no operation*
----	330°	Verify no operation*

***NOTE:** **Continuous current rating is maximum three (3) times nominal current rating (5A to 15A).**

ZONE 2 TWO PHASE TEST

1. Short - circuit the contacts of the time-lag relay by inserting suitable wires with COMBIFLEX pin connectors at both ends in the front of the terminal base between terminals 925:25 to 925:26 and 925:15 to 925:16 or set timers to 1 ms and install timers.

2. Repeat test procedure for ZONE 1 TWO PHASE TEST, see Table XI for min. and max. current levels.

TABLE XI

ZONE 2 TWO PHASE FAULT CHARACTERISTIC-PHASE B TO C (ZK_2, C_2) CHARACTERISTICS V_F=5V

Z LOOP (Ohms)	I TEST (Angle)	I TEST (I) (Amps) (Min - Max)
0.96	180°	4.95 - 5.47
0.968	172°	4.91 - 5.43
0.9	150°	5.28 - 5.84
----	0°	Verify no operation*
----	330°	Verify no operation*

***NOTE: Continuous current rating is maximum three (3) times nominal current rating (5A to 15A).**

3. Remove short-circuits made in step 1.

ZONE 3 TWO PHASE TEST

1. Short-circuit the contacts of the time-lag relay by inserting suitable wires with COMBIFLEX pin connectors at both ends in the front of the terminal base between terminals 925:25 to 925:26 and 925:15 to 925:16 or insert timers with the timers set to 1 ms.

2. Set test voltages and phase angles as follows:

   $V_A(R_U)$ = 17.32 volts @ 0°

   $V_B(S_U)$ = 10.00 volts @ 150°

   $V_C(T_U)$ = 10.00 volts @ 210°

   Set MASTER Unit (A0) current channel to 180 degrees.

3. Repeat test procedure for ZONE 1 TWO PHASE TEST, see Table XII for min. and max. current levels.

TABLE XII

ZONE 2 TWO PHASE FAULT CHARACTERISTIC-PHASE B TO C (L_1, B_1 CHARACTERISTICS)

Z LOOP (Ohms)	I TEST (Angle)	I TEST (I) (Amps) (Min - Max)
1.92	180°	4.95 - 5.47
1.936	172°	4.91 - 5.43
1.80	150°	5.28 - 5.84
----	0°	Verify no operation*
----	330°	Verify no operation*

***NOTE: Continuous current rating is maximum three (3) times nominal current rating (5A to 15A).**

4. If short-circuits were made in step 1, remove them at this time and replace TK_2 and TK_3 timers that were removed.

THREE-PHASE TEST

A Zone 1 30 operation is used to verify correct 30 operation.

1. Connections to relay remain the same as phase-neutral tests. Repeat steps 1 through 7 of ZONE 1 REACH TEST, A-N.

2. With the test system properly connected to the relay, set the test voltages, currents and phase angles as follows:

   $V_A(R_U)$ = 3.0 volts @ 0°

   $V_B(S_U)$ = 3.0 volts @ 120°

   $V_C(T_U)$ = 3.0 volts @ 240°

   I_A(RI) = 5 amps @ 82°

   IB(SI) = 5 amps @ 202°

   I_C(TU) = 5 amps @ 322°

3. Initiate the test system by pressing the MASTER Unit INITIATE Control Switch.

4. Increase the 30 current outputs until the MONITOR light begins to flicker and/or the tone signal starts to break. Read and record value of current where relay operated.

5. Deinitiate output by pressing the MASTER Unit INITIATE Control Switch.

6. Replace TK2 and TK3 timers that were removed in Step 1.

ZONE 2 TIMER TEST, A-N

1. Set ZONE 2 timer to the desired setting.

2. Set up of controls and settings are the same as for the ZONE 2 REACH TEST, A-N. Set test voltages at 9 volts and set test current at the phase angle and magnitude equal to the recorded reach value.

3. Move TRIP R lead and -125VDC lead from MASTER Unit to STOP/MONITOR binding posts on EPOCH-IV. Connect MASTER Unit TIMER START binding posts to START binding posts on EPOCH-IV. See FIGURE B for connections.

4. Set EPOCH-IV or TV-2 to START on N.O. contact closure and to STOP on voltage applied.

5. Initiate timing test system by pressing the MASTER Unit INITIATE Control Switch.

6. When the voltage and current is applied to the relay, the timer should start running. When the relay trips the timer should stop. Deinitiate the test system.

7. Reset targets R, T_{K2} and U. Repeat test if timer is adjusted.

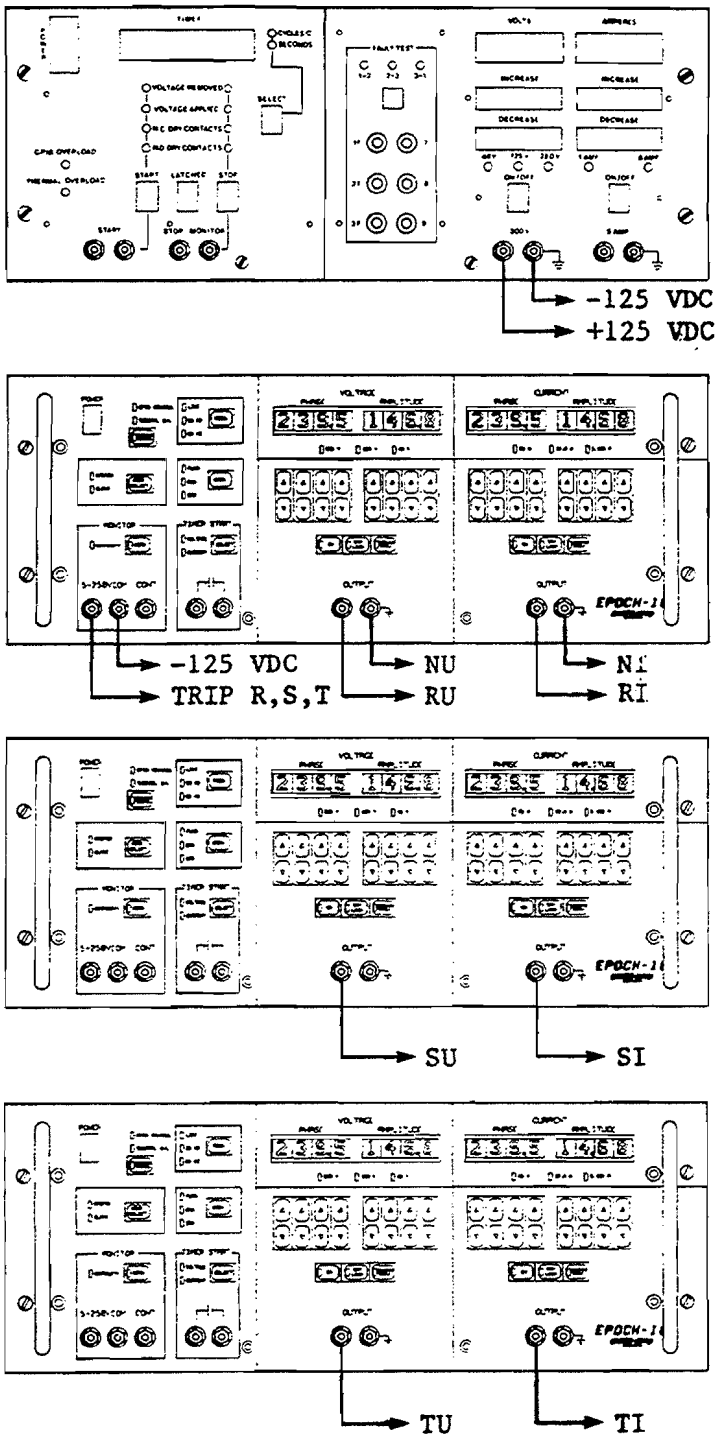
ZONE 3 TIMER TEST, A-N

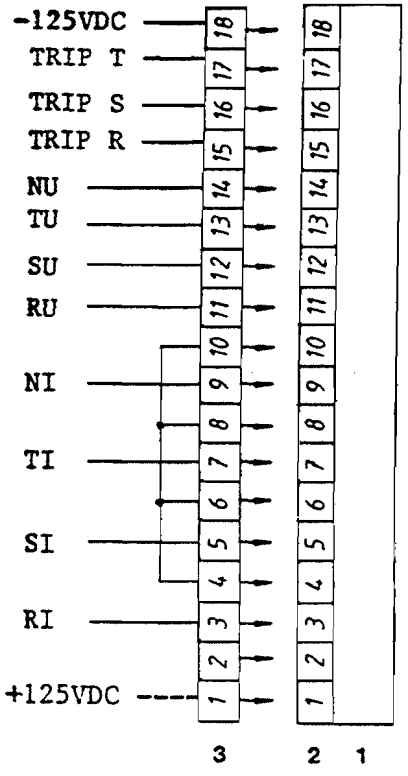
1. Set Zone 3 timer to the desired setting.

2. Set up of controls and settings are the same as for the ZONE 3 REACH TEST, A-N. Set test voltages at 9 volts and set test current at the phase angle and magnitude equal to the recorded reach value.

3. Repeat Steps 3 through 6 for the ZONE 2 TIMER TEST.

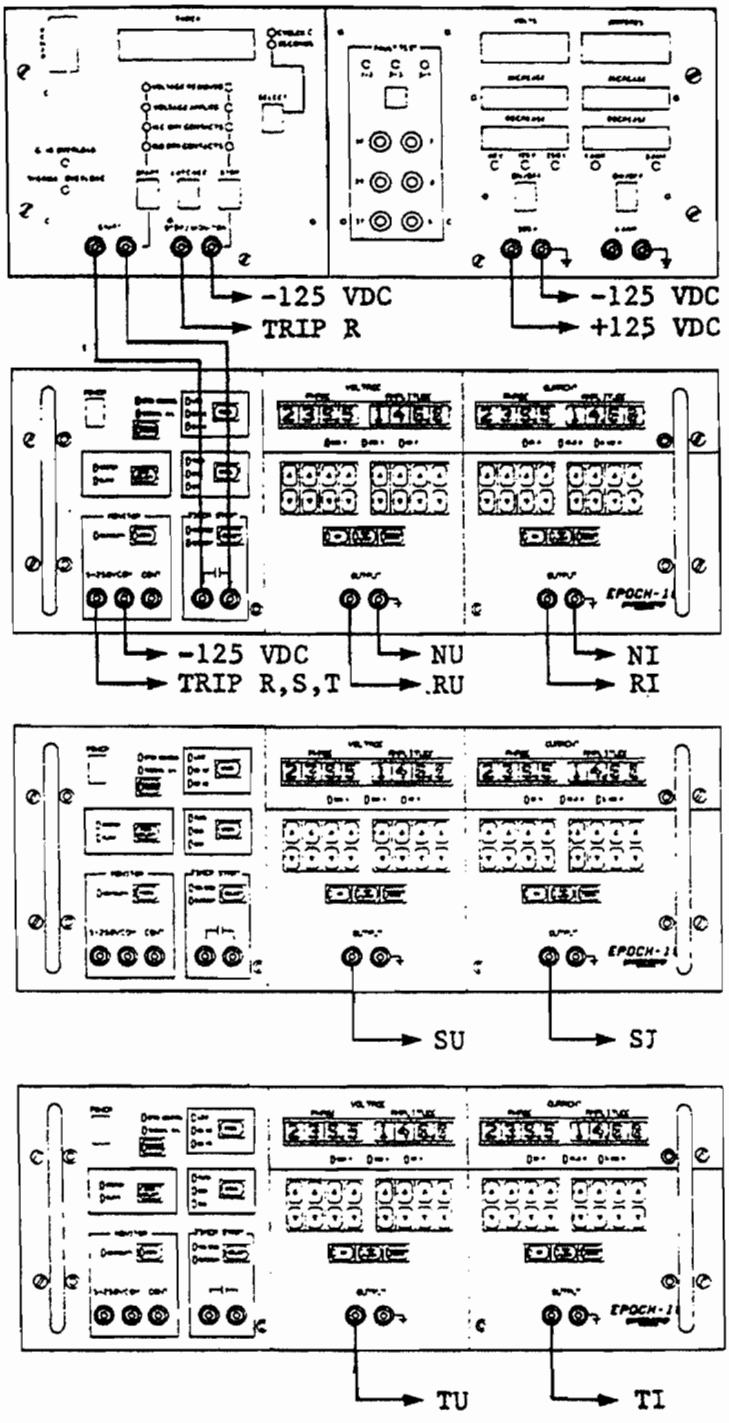
4. Reset targets R, T_2, T_3 and U. Repeat test if the timer is adjusted.

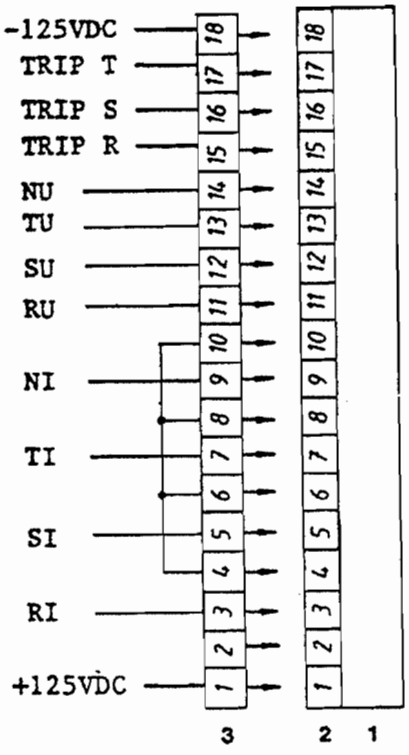




1 *Distance Relay*
2 *Test switch RTXP 18 in distance relay*
3 *Test handle RTXH 18*

FIGURE A: TEST CONNECTIONS BETWEEN RAZFE, TEST HANDLE AND EPOCH-10, IV





1 *Distance Relay*
2 *Test switch RTXP 18 in distance relay*
3 *Test handle RTXH 18*

FIGURE B: TEST CONNECTIONS BETWEEN RAZFE, TEST HANDLE AND EPOCH-10, IV

AVO INTERNATIONAL

INSTRUCTION MANUAL

For

MACSART® Command Set:

EPOCH-I/10® and EPOCH-II/20®

This manual applies EPOCH firmware versions 2.0 and greater.

Any software developed on versions prior to 2.0 will require changes and/or modifications as outlined in section 5.0 of this manual.

EPOCH®, MACSART®, TestPac™, and MasterTest™ ARE TRADEMARKS OF MULTI-AMP CORPORATION

MACSART training disc is available to be used with a Hewlett Packard Integral computer on request.

Please ask for Part Number 10017.

It is essential that this instruction book be read thoroughly before putting the equipment in service.

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Part N° 12339
Rev. 1

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1.0 Introduction

Since the command sets are the same for both the EPOCH-I® and EPOCH-10® test sets, they will be referred to in this manual as EPOCH-1/10.*

The EPOCH-I/10 relay test set when equipped with the General Purpose Interface Bus (GPIB) becomes a fully programmable, automatic test system. Any controller or computer that conforms to the standard IEEE-488 (1978) "Digital Interface for Programmable Instrumentation" is capable of operating the EPOCH-I/10 Test System via the GPIB and the EPOCH-I/10 command set. The EPOCH-I/10 command set is structured such that the user has quick and easy duplication of all front panel operations. In addition, all amplitude and/or phase angle values may be step changed or slewed to new values at a programmed rate. Up to sixteen user-programmed event driven commands may be executed internally - which allows for testing of a relay through the GPIB, then display or print the resulting characteristics of the relay.

2.0 Scope

The software versions 2.40 to 2.42 for the EPOCH-I/10 contain several new reliability enhancements. The first enhancement is for the EPOCH-I/10 distortion alarm where the channel is turned off on recognition of distortion before the alarm is sounded. This change allows the amplifier to operate in an "open loop" mode for a much lower period of time than before. Another change terminated the distortion acknowledge phase when a SLAVE unit lost timing signals (since all timing is based on these timing signals).

The second major revision involved the amplifier turn-on modes. In versions 2.40 to 2.42, the on/off control routine has been rewritten to allow for the case where both channels may be turned on synchronously or asynchronously with a single switch code. In versions after 2.41, a software command was added to allow a serial poll of the MONITOR binding posts, see Section 4.11.4.1 for details. Please refer to section 5.0 for details on versions 1.3 to 2.42 changes.

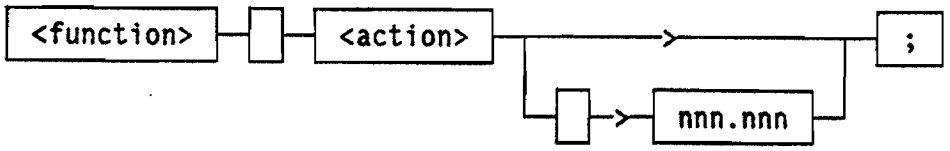
(*)The same applies for Multi-Amp Models EPOCH-II® and EPOCH-20®, they will be referred to as EPOCH-II/20 for brevity.

3.0 MACSART Command Set

The EPOCH-I/10 command set is powerful, versatile and user friendly. The command set consists of ten functions, thirty-one basic actions and four query functions. The valid combinations of functions and actions yields forty-five pre-programmed output states. Only the parameters which are being used or changed need to be addressed.

3.1 Structure

All MACSART commands are of a common structure, shown below:



where -

<function>	=	One of fourteen functions.
<action>	=	One of thirty-one actions.
nnn.nnn	=	Optional numeric input; internally using six digits, three whole digits and three fractional digits. Internally, the level and phase data are four places at all times, based on the displayed resolution. The delay action code buffer is the exception by having no fractional digits, the effective range is from zero to 999.

3.2 Function Code Summary

The valid function codes are:

1) CHANGE - Allows access to the Execution Queue and to alter the software control paths.

2) CURRENT - Allows access to change the current channel state.

3) F_SOURCE - Determines the frequency (line, fifty or sixty).

4) HARMONIC - Selects the harmonic frequency for the voltage and current outputs which can be either fundamental, second or third harmonic.

5) MAIN - This function will initiate or de-initiate the current or voltage output on a MASTER unit whose output channels are in the local initiate mode. When two or more units are interconnected (via the EPOCH-I/10 Interconnect Bus) this function will also initiate or de-initiate all SLAVE units whose outputs are the local initiate mode.

6) MONITOR - Turns the monitor horn on or off.

7) PH_REF - Phase reference selection when two or more units are interconnected, one unit will source all timing (MASTER) to all other units (SLAVE). For a single unit, the operational mode is always MASTER.

8) TIMER - Allows control over the timer start dry relay contacts.

9) VOLT - Allows access to change the voltage channel state.

10) = - (equal) Renames any function or action code.

3.3 Action Code Summary

The valid action codes are:

1) LEVEL - Set the amplitude of either the current or the voltage outputs and requires a numeric input equal to the desired amplitude in units of rms volts or amperes.

2) D_LEVEL - Establishes an increment-of-change (delta rate) of the voltage or current amplitude and requires a numeric input equal to the incremental amplitude in units of rms volts or amperes.

3) S_LEVEL - Provides the final amplitude value of the current or voltage output and requires a numeric input equal to the desired final amplitude value in units of rms volts or amperes.

4) PHASE - Applies to both current and voltage output phase and requires a numeric input equal to the desired phase - referenced as clockwise vector rotation in degrees.

5) D_PHASE - Establishes a rate-of-change (delta rate) of the phase angle with respect to the reference vector and requires a numeric input equal to the incremental phase angle in degrees.

6) S_PHASE - Provides the final phase angle of the current or voltage channel and requires numeric input equal to the final phase angle in degrees.

7) DELAY - Sets the delay between each increment when a delta is being performed. Requires a numeric input from zero to 999 corresponding to the number of cycles between each delta update.

8) ON - Places the given function in the on state.

9) OFF - Places the given function in the off state.

10) INIT - Places current and/or voltage outputs in the initiate mode. When used with the MAIN function, this will initiate all outputs that are in the initiate mode locally.

11) DE_INIT - Places current and/or voltage outputs under control of on/off only. When used with the MAIN function, this will de-initiate all outputs that are presently in the local initiate mode.

12) TAP1 - Selects the lowest tap for voltage or current for the EPOCH-I/10.

13) TAP2 - Selects the middle tap for voltage or current for the EPOCH-I/10.

14) TAP3 - Selects the highest tap for voltage or current for the EPOCH-I/10.

15) GPIB - Allows immediate execution of a state change command, allows altering control paths and provides reset capability.

16) GET - Used in conjunction with the CHANGE function, GET allows the numeric command to be placed in the Execution Queue. When in execute mode, the command will not be executed until a Group Execute Trigger from the system controller has been detected in the present software cycle.

17) M_OPEN - Used in conjunction with the CHANGE function, M_OPEN allows the numeric command to be placed in the Execution Queue. When in execution mode, the command will not be executed until both the Continuity AND Volts-Applied monitor inputs are in the inactive state in the present software cycle.

18) M_CLOSE - Used in conjunction with the CHANGE function, M_CLOSE allows the numeric command to be placed in the Execution Queue. When in execute mode, the command will not be executed until Continuity input OR the Volts-Applied monitor input is found active in the present software cycle.

19) ZERO_PH - Used in conjunction with the CHANGE function, ZERO_PH allows the numeric command to be placed in the Execution Queue. When in execution mode, the command will be executed when there has been a positive zero crossing detected on the Phase Reference in the present software cycle.

20) EVENT - Used in conjunction with the CHANGE function, EVENT allows the numeric command to be placed in the Conditional Execution Queue. When in execute mode, the command is executed without any tests on a condition. This allows an entire group of commands to be executed when a given condition becomes true or active.

21) VCHANNEL - Specifies that the timer start contacts follow the state of the voltage channel where 'closed' is on and 'open' is off.

22) ICHANNEL - Specifies that the timer start contacts follow the state of the current channel where 'closed' is on and 'open' is off.

23) MASTER - Specifies the addressed unit as the timing source for all other units on the Interconnect Bus.

24) SLAVE - Specifies that an external timing source is the source against which that unit's outputs are being referenced.

25) IDLE - A timing source has not been specified for reference.

26) LINE - Specifies the input line as frequency source.

27) FIFTY - Specifies the fifty Hertz oscillator as the frequency source.

28) SIXTY - Specifies the sixty Hertz oscillator as the frequency source.

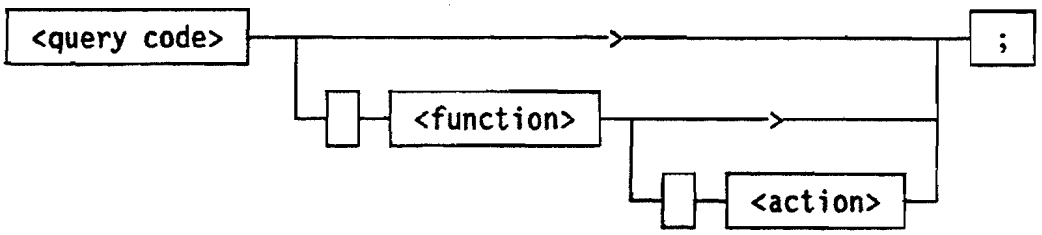
29) FUND - Specifies that the output frequency is at fundamental mode - note that this is independent of the phase reference.

30) SECOND - Specifies that the output frequency is the second harmonic - note that this is independent of the phase reference.

31) THIRD - Specifies that the output frequency is the third harmonic - note that this is independent of the phase reference.

3.4 Query Code Summary

The query codes allow the user to inspect the settings of the two buffers; Set? (desired state) and Run? (output state). Syntactically, the form of any query code is as follows:



where <query code> is one of the following reserved words:

1) RUN? - Returns any of the values shown in the RUN? buffer (i.e. the present output status).

2) SET? - Returns any of the values shown in the SET? buffer (i.e. the user's desired state).

3) ERR? - Returns the error status of the unit.

4) STATUS? - Queries the EPOCH-I/10 for the magnitude and/or phaseangles of the current and/or voltage channel (see the CHANGE numeric 10.xx command).

3.5 Allowed Function / Action Code Pairs

Valid actions for a given function are listed below:

	LEVEL	PHASE	D_PHASE	D_LEVEL	S_PHASE	S_LEVEL	ON	OFF	INIT	DE_INIT	TAP1	TAP2	TAP3	DELAY	GPIB	GET
CHANGE															■	■
CURRENT	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
F_SOURCE								■								
HARMONIC																
MAIN									■	■						
MONITOR							■	■								
PH_REF																
TIMER																
VOLT	■	■	■	■	■	■	■	■	■	■	■	■	■	■		

Table 1: MACSART Allowed Function / Action Codes

	M_OPEN	M_CLOSE	ZERO_PH	EVENT	VCCHANNEL	ICCHANNEL	MASTER	SLAVE	IDLE	LINE	FIFTY	SIXTY	FUND	SECOND	THIRD
CHANGE	■	■	■	■											
CURRENT															
F_SOURCE										■	■	■			
HARMONIC													■	■	■
MAIN															
MONITOR															
PH_REF							■	■	■						
TIMER					■	■									
VOLT															

Table 1: MACSART Allowed Function / Action Codes (continued)

3.6 Control Structure

3.6.1 Set? / Run? Buffers

The control structure uses a state comparison technique for the control algorithm, where the user's input is stored in a desired state table, the Set? Buffer; while the hardware state is stored in another state table, the Run? Buffer. When the Set? and Run? Buffer locations do not match for a particular function, the state comparitor forces the hardware to another state.

For example, if the HARMONIC is currently in the FUND (fundamental) state and the Set? Buffer state is THIRD (harmonic); the state comparitor forces a state update to SECOND harmonic. At the next software cycle, the state comparitor still detects a difference - the hardware is at SECOND harmonic with the Set? state at THIRD harmonic. Another state update is forced which causes the harmonic to go to THIRD from second. Now the state comparitor detects equality between Set? and Run? harmonic states and no further state updates are necessary.

In the case of numeric states, such as output levels, the state comparitor works in a different manner. The desired numeric value is first checked against the upper and lower limits. If the value is in range, then the Set? value becomes the new state value. Once again, the Set? value forces a state update. The hardware is then updated with the new value and the hardware value is stored in the Run? buffer.

Note that hardware errors, such as Distortion, Bus Error and Thermal Overload disable the state comparitor to allow the error control routines to override the state update mechanism. The user may reassert control by enabling the Set?/Run? buffer comparitor through the 'CHANGE GPIB 70;' command (refer to section 3.1.3.2 for more details on Set? Buffer enabling).

Set? Buffer

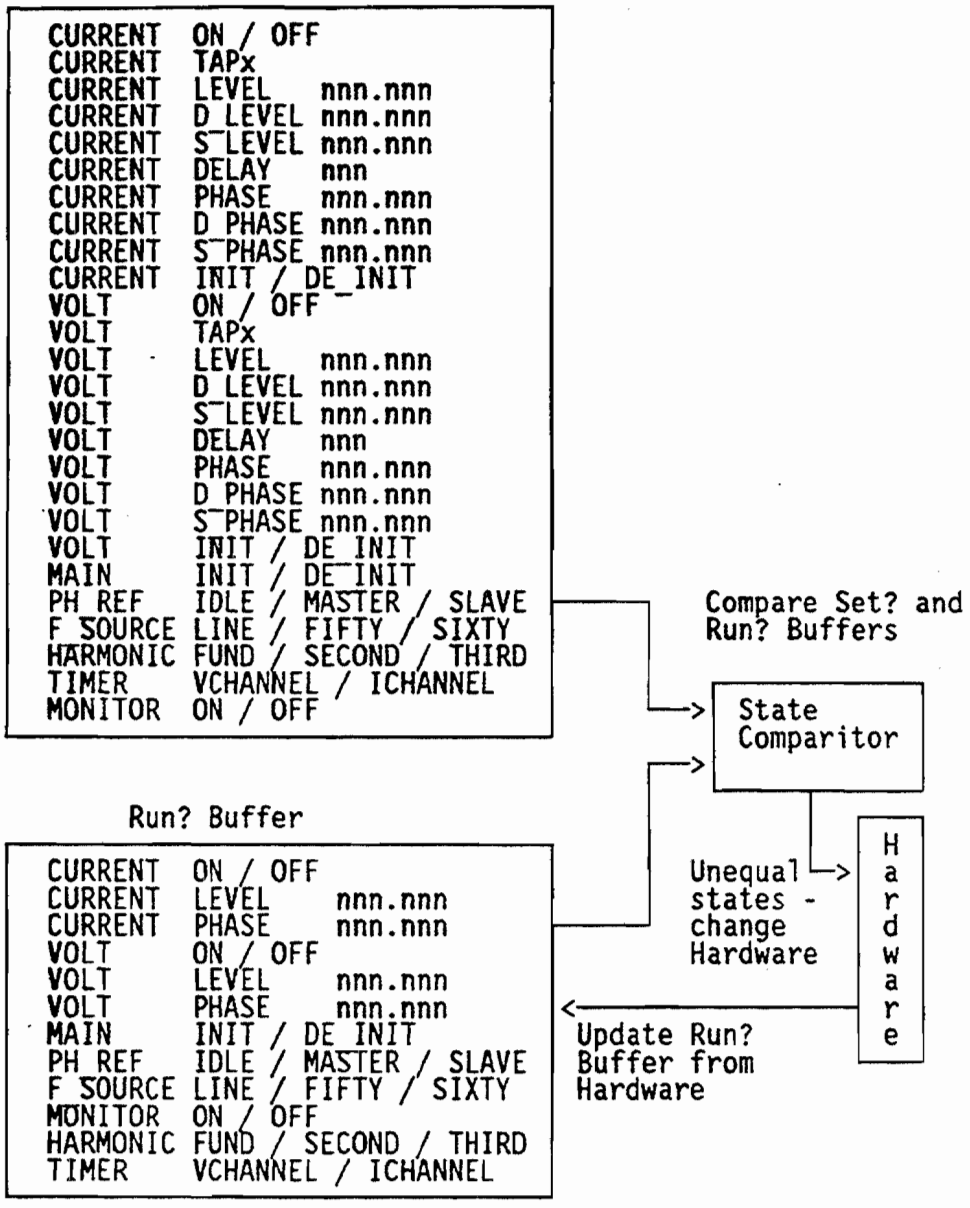


Figure 1: Set? and Run? Buffer Control Paths

3.6.2 'CHANGE' Command Paths

The 'CHANGE' command actually controls two distinct control paths. The 'GPIB' path is used to allow the user to control the queue itself and also bypasses the queue and goes directly to the command decoder. Additional capabilities are built in, such as the software reset and the Set? Buffer enable / disable command (which gates the state comparitor between the Set? and Run? Buffers). The other control path is the queue input buffers. These five buffers (GET, EVENT, M_CLOSE, M_OPEN and ZERO_PH) may contain user defined state change commands which are then stored on the queue for later execution. The actual status of the queue is determined by the input derived from the 'GPIB' buffer when in HALT or WAIT mode. The status of the queue in EXECUTE or IDLE mode is determined by the state change commands on the queue itself.

The queue is initialized to the HALT state on power-up. Entry into active mode is done by the operator sending a 'EXECUTE' command. The queue executive then tests the size of the queue. If the queue is empty, the mode returns to HALT. If the size is non-zero, then the executive checks for a valid command. If it is not valid, the mode returns to HALT after issuing an 'Execution Error' message. If it is valid, the command's event parameter is then tested. If the event is false, the executive assumes the WAIT mode. The command's event is re-tested on the next software cycle. When the event is true, the executive now assumes EXECUTE mode. The command is decoded and parsed into the circular switch-code queue. The circular queue is read ONCE every software cycle and the switch codes are passed to the main loop as input. Note that the next linear queue command is NOT processed until the circular queue is completely empty. When the circular queue is empty, the executive now increments the command pointer. The command pointer is compared to the queue size. If the pointer is greater, then HALT mode is asserted. If the pointer is less than or equal to the size, the executive now tests for a pause command. If such a command had been sent, the executive now enters PAUSE mode and stays in that mode until a new execute command has been given. If no pause command has been sent or if PAUSE mode has been released by an execute command, the executive now enters WAIT mode and begins the check for a valid command, completing the queue processing loop.

The user programs the Queue through the 'CHANGE ' buffer interface - the allowed conditions are: GET, ZERO_PH, M_OPEN, M_CLOSE and EVENT.

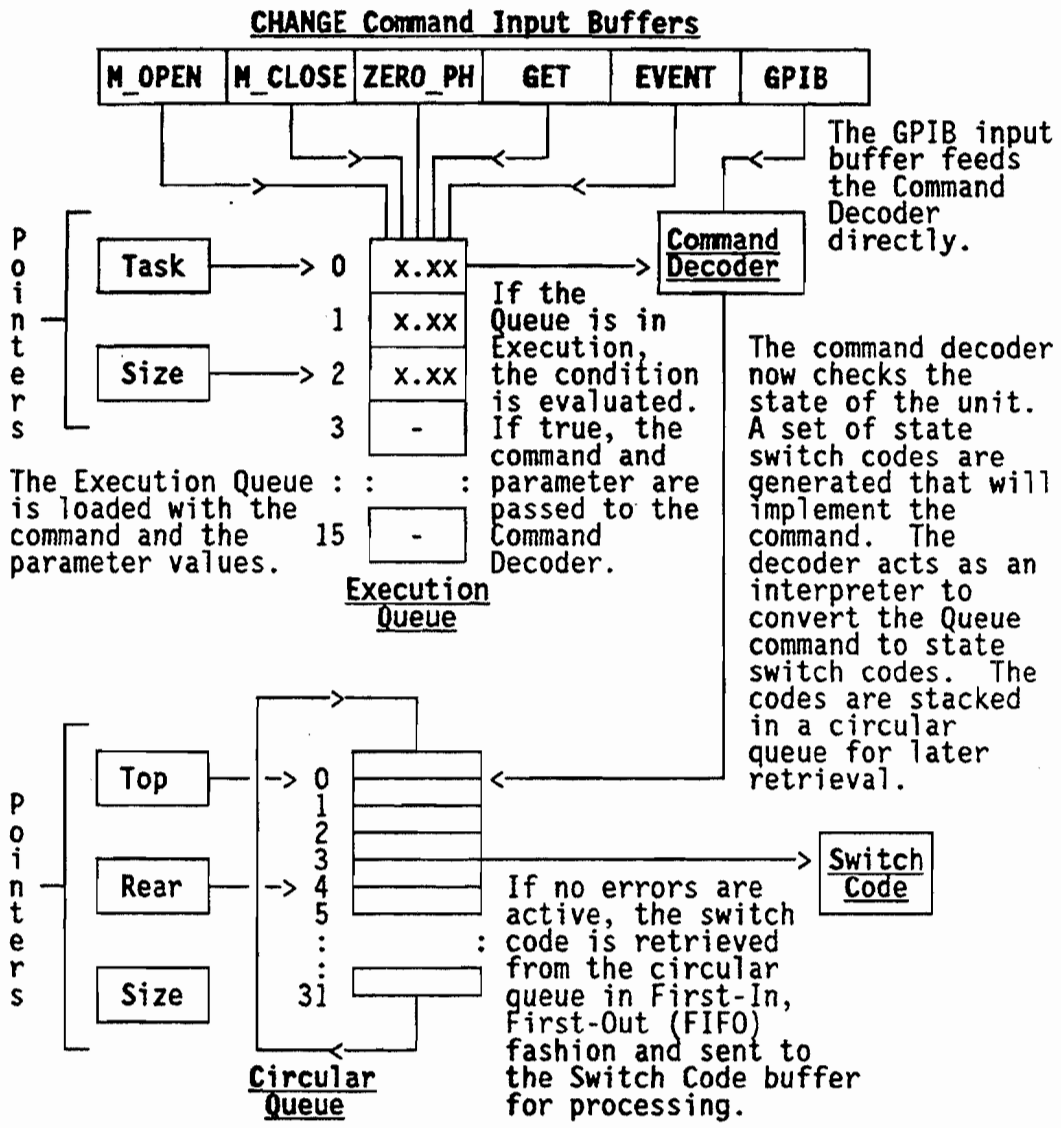


Figure 2: CHANGE Command Paths

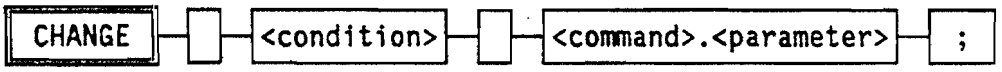
4.0 MACSART Command Definitions

4.1 CHANGE

Provides the user interface to the Execution Queue. The Conditional Execution Queue allows the user to implement a state change in the EPOCH upon a user-defined condition becoming true in the hardware.

The Execution Queue is a linear array composed of sixteen words of user-programmable commands. The commands are executed in a First In-First Out (FIFO) order. The user has control over the queue contents by specifying the condition, the state change command and the parameters affected by the state change command. When in execution mode, the condition is tested for a returned "true" status. When that condition is true, then state change command is decoded and the parameters which affect the command are stored. The decoded command is now executed. On implementation of the command in hardware, the Queue Task Pointer is then incremented and the condition-testing is performed for the next state change command.

Syntax format is as follows:



where-

<condition> is one of six action codes specifically for the Execution Queue interface. The <command>.<parameter> specifies a command to be performed on the true status of the <condition>, and also a parameter list which affects the execution of the command dynamically.

4.1.1 <condition>

The <condition> in the CHANGE command may be one of the following:

GPIB — Provides a user interface to the Execution Queue, enable or disable the state comparitor and perform reset capability from a remote station. If the operator chooses to assert the on/off controls through the 'GPIB' condition, the off to on transition is synchronous with the phase reference and the on to off transition is asynchronous.

GET — Reserved for Execution Queue input; the GET condition allows the associated state change command and parameter to be placed on the queue. During execution, the command will be executed only on the receipt of a Group Execute Trigger from the system controller. Note that for version 2.42, this is an asynchronous mode. In other words, when the GET condition is used, the control software will perform the operation as soon as possible - not waiting for the zero-crossing interrupt to occur. Therefore, all on/off actions will not occur synchronously with the GET.

M_OPEN — Reserved for Execution Queue input; the monitor contacts OPEN allows the associated state change command and parameter to be placed on the queue. During execution, the command will be executed only when the monitor contacts are in the open state AND when the volts-applied input is inactive. This condition causes all on/off transitions to be asynchronous with the phase reference.

M_CLOSE — Reserved for Execution Queue input; the monitor contacts CLOSED allows the associated state change command and parameter to be placed on the queue. During execution, the command will be executed only when the monitor contacts are in the closed state OR when the volts-applied input has a voltage within the range of 5-250 Volts. This condition causes all on/off transitions to be asynchronous with the phase reference.

ZERO_PH — Reserved for Execution Queue input; the positive zero crossing condition allows the state change command and parameter to be placed on the queue. During execution, the command will be in the software cycle when the internal vector crosses zero in the positive direction. If the operator chooses to assert the on/off controls through the 'ZERO_PH' condition, the off to on transition is synchronous with the phase reference and the on to off transition is asynchronous.

EVENT — Reserved for Execution Queue input; the event condition allows the state change command to be placed on the queue. During execution, the command be executed immediately - EVENT is a condition which returns a true value at all times. If the operator chooses to assert the on/off controls through the 'EVENT' condition, the off to on transition is synchronous with the phase reference and the on to off transition is asynchronous.

4.1.2 <parameter> / Flags Register

The <parameter> numeric field allows the user to program a combination of output channels (current amplitude / phase - voltage amplitude / phase) for <state> to use. The range of the fractional portion is from zero to sixty-three.

The <parameter> is encoded as follows:

BIT	NAME	DECIMAL VALUE	DESCRIPTION
7		128	Don't care (always set to zero).
6		64	Don't care (always set to zero).
5	ROLL	32	When set to a logic one, this bit enables the delta phase function to start over at its initial-value (PHASE) when the step-value (S_PHASE) is reached. Note that this bit overrides the SWING bit for any phase delta function. A zero disables roll.
4	SWING	16	When set to a logic one, this bit enables any delta function to reverse direction on reaching the step-value (S_LEVEL or S_PHASE). When the initial -value (LEVEL or PHASE) is reached, the direction reverses again and the delta approaches the step-value. The net effect is an "oscillating" phase and/or amplitude from its initial-value to the final-value. A logic zero disables this function where a delta function will stop on reaching its step-value (S_LEVEL or S_PHASE).
3	E PHASE	8	When set to a logic one, this bit allocates the voltage channel phase for use by the associated command. When set to a logic zero, the voltage channel phase is not affected by the command.
2	E AMPLITUDE	4	When set to a logic one, this bit allocates the voltage channel amplitude parameter for use by the associated command. When set to a logic zero, the voltage channel amplitude is unaffected by the command.
1	I PHASE	2	When set to a logic one, this bit allocates the current channel phase as a parameter for use by the associated state change

			command. when set to a logic zero, the current channel phase is unaffected by the command.
0	I AMPLITUDE	1	When set to a logic one, this bit allocates the current channel amplitude as a parameter for use by the associated state change command. When set t a logic zero, the current channel amplitude is unaffected by the command.

The Flags Register is the value of the parameter as returned by the command decoder during execution of the given queue command. As an aid to programmers, the 'RUN? CHANGE;' query command provides read back of the parameter which the command decoder used (see Section 3.11.2 for details).

4.1.3 <state>

There are four major <state>.<parameter> groups. The first section is the only one which is queue programmable. The remaining commands are available only through the 'GPIB' state.

There are two internal registers associated with the STEP and DELTA functions. Both registers govern the way in which the parameter data affects the STEP or DELTA function by replacing or deleting selected parameters from these registers. The FLAGS register is updated accordingly from the parameter in the state change command. When using the delta or step modes, the flags register contains either the parameter value, the STEP value or DELTA value as returned from the command decoder. When queried using the 'RUN? CHANGE;' command, the present value of the flags register is transmitted. Note that only the DELTA function may reset its own allocation bits under only two conditions. The first condition is when a zero-valued incremental value (D_LEVEL or D_PHASE) is encountered. The second condition is when the DELTA function reaches the final value (S_LEVEL or S_PHASE) when no ROLL or SWING bit is active.

Please note that the incremental level (D_LEVEL or D_PHASE) and the final value (S_LEVEL and S_PHASE) are buffered. The actual value used by the DELTA or STEP functions is a binary value. This binary value is generated **only** when the Set? comparitor is enabled. For example, if the Set? comparitor is disabled and the user sends a new current incremental value on the GPIB, the binary current incremental value is **NOT** changed since the Set? comparitor is disabled. However, if the user issues a Set? Buffer Enable command ('CHANGE GPIB 70;') or a RESTORE command ('CHANGE GPIB 19;') the binary incremental value will then be updated via the Set? / Run? comparitor.

The next section lists the allowed Conditional Execution Queue state commands along with the allowed parameter data and the STEP or DELTA function flag update status.

4.1.3.1 Programmable Queue Commands

The queue programmable state commands may also be used in the 'CHANGE GPIB' mode. A description of the state commands are as follows:

0.nn **ON to OFF**

On command decode, the amplitude parameter bits are examined for allocation. If allocated, the present ON/OFF state of the channel is obtained. If the channel is ON, the decoder then passes an update command which allows the next software loop to turn that channel OFF. If the channel is OFF, the channel is de-allocated; that particular channel will not be affected by the command.

The allowed parameters are:

I AMPLITUDE
E AMPLITUDE

The parameter values may be: 0, 1, 4, 5.
FLAGS register is updated with the parameter value when executed on the queue.

1.nn **OFF to ON**

On command decode, the amplitude parameter bits are examined for allocation. If allocated, the present ON/OFF state of the channel is obtained. If the channel is OFF, the decoder then passes an update command which allows the next software loop to turn that channel ON. If the channel is ON, the channel is de-allocated; the new state will not affect that particular channel.

The allowed parameters are:

I AMPLITUDE
E AMPLITUDE

The parameter values may be: 0, 1, 4, 5.
FLAGS register is updated with the parameter values when executed on the queue.

2.nn **OFF to STEP**

On command decode, both phase and amplitude parameter bits are examined for allocation. If allocated, the present ON/OFF state of the channel(s) are obtained. If any channel is OFF, the decoder then passes an update command which allows the control software to turn that channel ON and then to STEP. Note that the 'OFF' implies a condition that is used to determine eligibility for the STEP function. In other words, if the channel is allocated and is in the ON state, the allocation bits for that channel are reset - no STEP function will occur for that channel.

The allowed parameters are:

I AMPLITUDE
I PHASE
E AMPLITUDE
E PHASE

The parameter values may be: 0-15.
STEP allocation flag = (Parameters AND 15)
FLAGS is updated with the STEP allocation value when executed on the queue.

3.nn **STEP to OFF**

On command decode, the present value of the STEP allocation flag is examined. For any parameter that the user provides for allocation, the appropriate bit is RESET in the STEP allocation value. The command decoder now looks at the present state of the outputs. If the channel is OFF, there is no need to turn that channel off - but the allocation bit for that channel is still reset. For example, if the present value of the STEP allocation flag is five (which reflects that the user has previously forced both the current and voltage amplitudes to the S_LEVEL with both current and voltage channels ON) and the user issues a 'CHANGE GPIB 3.01', the effect is to set the STEP allocation value to four and also to turn the current channel off. The FLAGS value is now one, since the parameter value of the command is one.

The allowed parameters are:

I AMPLITUDE
I PHASE
E AMPLITUDE
E PHASE

The parameter values may be: 0-15.
STEP allocation flag = (Parameters EXCLUSIVE-OR STEP) AND STEP AND 15
FLAGS register is updated with the parameters after command decode when executed on the queue.

4.nn **ON to STEP**

On command decode, both phase and amplitude parameter bits are examined for allocation. If allocated, the present ON/OFF state of the channel(s) are obtained. If any channel is OFF, the decoder then ignores the command for that channel - the allocation bits are RESET by the decoder to reflect this. If the channel is ON, the decoder then forces a STEP function for the appropriate channel(s). If both channels are OFF, then the command is ignored - no STEP function will result and the new value for the STEP allocation will be zero.

The allowed parameters are:

I AMPLITUDE
I PHASE
E AMPLITUDE
E PHASE

The parameter values may be: 0-15.
STEP allocation flag = (Parameters AND 15)
FLAGS register is updated with STEP when executed on the queue.

5.nn **STEP to ON**

On command decode, the present value of the STEP allocation flag is examined. For any parameter that the user provides for allocation, the appropriate bit is RESET in the STEP allocation value. The command decoder now looks at the present state of the outputs. If the channel is ON, there is no need to turn that channel on - but the allocation bit for that channel is still reset. For example, if the present value of the STEP allocation flag is five (which reflects that the user has previously forced both the current and voltage amplitudes to the S_LEVEL and assuming that the current channel is OFF); and the user issues a 'CHANGE GPIB 5.01', the effect is to set the STEP allocation value to four and also to force the current channel ON. The FLAGS value is now one, since the parameter value of the command is one.

The allowed parameters are:

I AMPLITUDE
I PHASE
E AMPLITUDE
E PHASE

The parameter values may be: 0-15.
STEP allocation flag = (Parameters EXCLUSIVE-OR STEP) AND STEP AND 15
FLAGS register is updated with the parameter when executed on the queue.

6.nn **OFF to DELTA**

On command decode, both phase and amplitude parameter bits are examined for allocation. If allocated, the present ON/OFF state of the channel(s) are obtained. If any channel is OFF, the decoder then passes an update command which allows the control software to turn that channel ON and then to DELTA. Note that the 'OFF' implies a condition that is used to determine eligibility for the DELTA function. In other words, if a channel is ON, then the DELTA allocation bits are reset. After the command decode and prior to the implementation of the DELTA function, the incremental values (D_LEVEL and D_PHASE) are examined for non-zero values for all allocated level or phase bits. If any incremental value is zero, then that level or phase allocation bit is RESET.

The allowed parameters are:

ROLL
SWING
I AMPLITUDE
I PHASE
E AMPLITUDE
E PHASE

The parameter values may be: 0-63.
DELTA allocation flag = (Parameters AND 63)
FLAGS register is updated with DELTA when executed on the queue.

7.nn DELTA to OFF

On command decode, the present value of the DELTA allocation flag is examined. For any parameter that the user provides for allocation, the appropriate bit is RESET in the DELTA allocation value. In addition, the output on/off state is examined for the parameters passed by the queue executive. If a channel is ON, then the decoder issues a command to turn it OFF. For example, if the present value of the DELTA allocation flag is five (which reflects that the user has previously forced both the current and voltage amplitudes to ramp with the current channel ON and the voltage channel OFF); and the user issues a 'CHANGE GPIB 7.05', the effect is to set the DELTA allocation value to zero and also to turn the current channel off. The FLAGS value is now five, since the parameter value of the command is five. In addition, the ROLL and SWING bits may be reset in this manner. If no phase or amplitude function is specified, then no channels will be turned off.

The allowed parameters are:

ROLL
SWING
I AMPLITUDE
I PHASE
E AMPLITUDE
E PHASE

The parameter values may be: 0-63.
DELTA allocation flag = (Parameters XOR DELTA) AND DELTA AND 63.
FLAGS register is updated with DELTA when executed on the queue.

8.nn ON to DELTA

On command decode, both phase and amplitude parameter bits are examined for allocation. If allocated, the present ON/OFF state of the channel(s) are obtained. If any channel is OFF, the decoder then ignores that parameter and also resets the appropriate allocation bit. Note that the 'ON' implies a condition that is used to determine eligibility for the DELTA function. In other words, if the output is OFF, then the allocation bits are RESET for that channel. After the command decode and prior to the implementation of the DELTA function, the incremental values (D_LEVEL and D_PHASE) are examined for non-zero values. If any incremental value is zero, then that level or phase allocation bit is RESET.

The allowed parameters are:

ROLL
SWING
I AMPLITUDE
I PHASE
E AMPLITUDE
E PHASE

The parameter values may be: 0-63.
DELTA allocation flag = (Parameters AND 63)
FLAGS register is updated with DELTA when executed on the queue.

9.nn **DELTA to ON**

On command decode, the present value of the DELTA allocation flag is examined. For any parameter that the user provides for allocation, the appropriate bit is RESET in the DELTA allocation value. In addition, the output on/off state is examined for the parameters passed by the queue executive. If a channel is OFF, then the decoder issues a command to turn it OFF. For example, if the present value of the DELTA allocation flag is twenty-one (which reflects that the user has previously forced both the current and voltage amplitudes to ramp with both current and voltage channels ON with the SWING effect) and the user issues a 'CHANGE GPIB 9.17', the effect is to set the DELTA allocation value to four and also to turn the current channel off. In addition, the SWING bit has been reset. The delta will now stop for the voltage channel when the voltage channel reaches the final value (or S_LEVEL). The FLAGS value is now seventeen, which was the parameter value on entry in the command decoder. In addition, the ROLL and SWING bits may be reset in this manner. If no phase or amplitude function is to be reset, then no channels will be turned off.

The allowed parameters are:

ROLL
SWING
I AMPLITUDE
I PHASE
E AMPLITUDE
E PHASE

The parameter values may be: 0-63.
DELTA allocation flag = (Parameters XOR DELTA) AND DELTA AND 63
FLAGS register is updated with the returned parameter when executing on the queue.

10.nn REPORT

Latch present state of selected outputs and issue a Service Request (SRQ) to the Controller (the user's computer with a IEEE-488 Controller Interface). If the user responds with an 'ERR?' query, the response would be 'STATUS? message' in order to notify the user that new output conditions have been latched. (See Section 4.11.3 on the STATUS? command for the retrieval of the output conditions and Section 4.11.4 on the 'ERR?' query command.)

The allowed parameters are:

I AMPLITUDE
I PHASE
E AMPLITUDE
E PHASE

The parameter values may be: 0-15.
FLAGS register is updated with (Parameter AND 15).

12.nn DELAY

Delay execution of the next queue command for 'nn' (decimal) number of cycles. The range of nn is from zero to sixty three. This command may not be used in the 'CHANGE GPIB' mode. Due to the asynchronous nature of the software loop time with respect to the hardware cycle time, the actual value of the delay in hardware cycles may deviate plus or minus one cycle. The FLAGS register is updated with the parameter.

19.nn RESTORE

Allow the Set? Buffer to update the hardware. This command may not be used in the 'CHANGE GPIB' mode. The Set? bit in the FLAGS register is affected. When the entire Set? / Run? buffer differences are satisfied, the Set? buffer comparitor is disabled. Note that the FLAGS register may be interrogated by use of a 'RUN? CHANGE;' command. The output is given in Binary Coded Decimal. No parameter information is necessary, although the FLAGS register is updated from the parameter.

4.1.3.2 Control Commands

The remaining eight commands are not programmable - they can only be executed through the 'CHANGE GPIB' interface. There are three major groups - the first group (70, 71) allows changing of the enable bit of the Set? / Run? state comparitor. The second group (80 - 83) allows control over the status of the Execution Queue. The last group (98, 99) involves remote reset capability. These commands do not require a parameter field entry - they may be entered in 'CHANGE GPIB nn;' form.

70 - Enable SET? buffer command processing.
71 - Disable SET? buffer command processing.
80 - Execute program in the Conditional Execution Queue / execute next instruction (valid for Pause mode only).
81 - Halt program execution and any delta functions.
82 - Pause execution (valid for an executing program in the Conditional Execution Queue).
83 - Reset the Conditional Execution Queue to Halt and clear the queue of any commands.
98 - Software reset (does not affect the phase reference (PH_REF) or frequency setting (F_SOURCE).
99 - Hardware reset (to power-up or default state).

4.1.4 Amplifier Off-to-On Modes via Queue

There are five conditions that may be programmed into the Execution Queue. The 'GPIB' condition is not queue programmable, but is included for reference. The table below depicts the turn-on and turn-off modes for the amplifiers for the five programmable conditions and the 'GPIB' condition.

A_On = Async On A_Off = Async Off S_On = Sync On X = No On or Off state change. <command>		<condition>					
		GET	MOPEN	MCLOSE	EVENT	ZEROPH	GPIB
0	ON to OFF	A_Off	A_Off	A_Off	A_Off	A_Off	A_Off
1	OFF to ON	A_On	A_On	A_On	S_On	S_On	S_On
2	OFF to STEP	A_On	A_On	A_On	S_On	S_On	S_On
3	STEP to OFF	A_Off	A_Off	A_Off	A_Off	A_Off	A_Off
4	ON to STEP	X	X	X	X	X	X
5	STEP to ON	X	X	X	X	X	X
6	OFF to DELTA	S_On	S_On	S_On	S_On	S_On	S_On
7	DELTA to OFF	A_Off	A_Off	A_Off	A_Off	A_Off	A_Off
8	ON to DELTA	X	X	X	X	X	X
9	DELTA to ON	X	X	X	X	X	X

Table 2: Amplifier On/Off Modes via CHANGE Command

4.1.5 Status Register

There is a status register available for the user to query the operation of the Execution Queue. The user may obtain the status at any time by using the 'RUN? CHANGE;' query. The individual bit assignment is as follows:

bit	identifier	functional states
7	EXEC	Logic one indicates execution mode for the Conditional Execution Queue and a logic zero indicates that the queue is either in HALT or WAIT mode.
6	PAUSE	Logic one indicates single command execution and a zero indicates EXEC or HALT mode.
5	SET?	Logic one indicates that the SET? buffer is enabled where state changes can be implemented by a difference between the RUN? and SET? buffers. A logic zero indicates that no state change will take place due to a SET? and RUN? buffer state difference.
4	HW ERR	Logic one indicates that a hardware error has occurred and the SET? buffer is locked out. In addition, if a hardware error occurred during a queue execution mode, the command is aborted and the queue status is forced into HALT mode. A logic zero indicates normal status.
3	EVENT	Logic one indicates the command's event became true in the Execution Queue. A logic zero indicates a WAIT state if the queue is in execution mode where the command's event has not returned a true condition.
2	ZERO	A logic one indicates a positive zero crossing has occurred during the current software cycle. This bit is set to a logic zero otherwise.
1	GET	A logic one indicates that the Group Execute Trigger has occurred during the current software cycle. This bit is set to a logic zero otherwise.
0	MONITOR	A logic one indicates activity on the Volts-Applied input OR by the Continuity input. A logic zero indicates an inactive state by Volts-Applied AND Continuity inputs.

4.1.6 Queue States

There are four Execution Queue states which may be read by the appropriate bits in the Status Register. The states and their bit patterns are as follows:

Queue State	Bit Value 76543210	Functional Description
BUSY	1x001xxx	The <state>.<parameter> command is currently being implemented in hardware.
HALT	00x00xxx	The Execution Queue is inactive.
WAIT	1x000xxx	The queue command is waiting to be executed due to the <condition> status returning a false status.
IDLE	0100xxxx	The queue is in single-step execution mode where a new 'execute' command must be sent to continue with the next <state>.<parameter> command in the queue.

Note that any digit represented by 'x' denotes a "don't care" state.

The PAUSE mode is a single-command execution mode for the Queue. When entered, this command sets the command pointer to one - pointing at the first command. At this time, a 'Run?' query is valid for the command to be executed NEXT. To execute the command, send 'CHANGE GPIB 80;' (execute) command. After execution, the pointer will point to the next valid command. If the command is invalid, then the queue enters the HALT state. Also, if the HALT command, 'CHANGE GPIB 81;' is given, the queue will be forced in the inactive state and any DELTA functions are forced inactive. The queue may be started up in the running state from the first queue location by using the 'CHANGE GPIB 80;' (execute) command.

4.2 CURRENT

Allows control of the current channel outputs.

Allowed Action Codes:

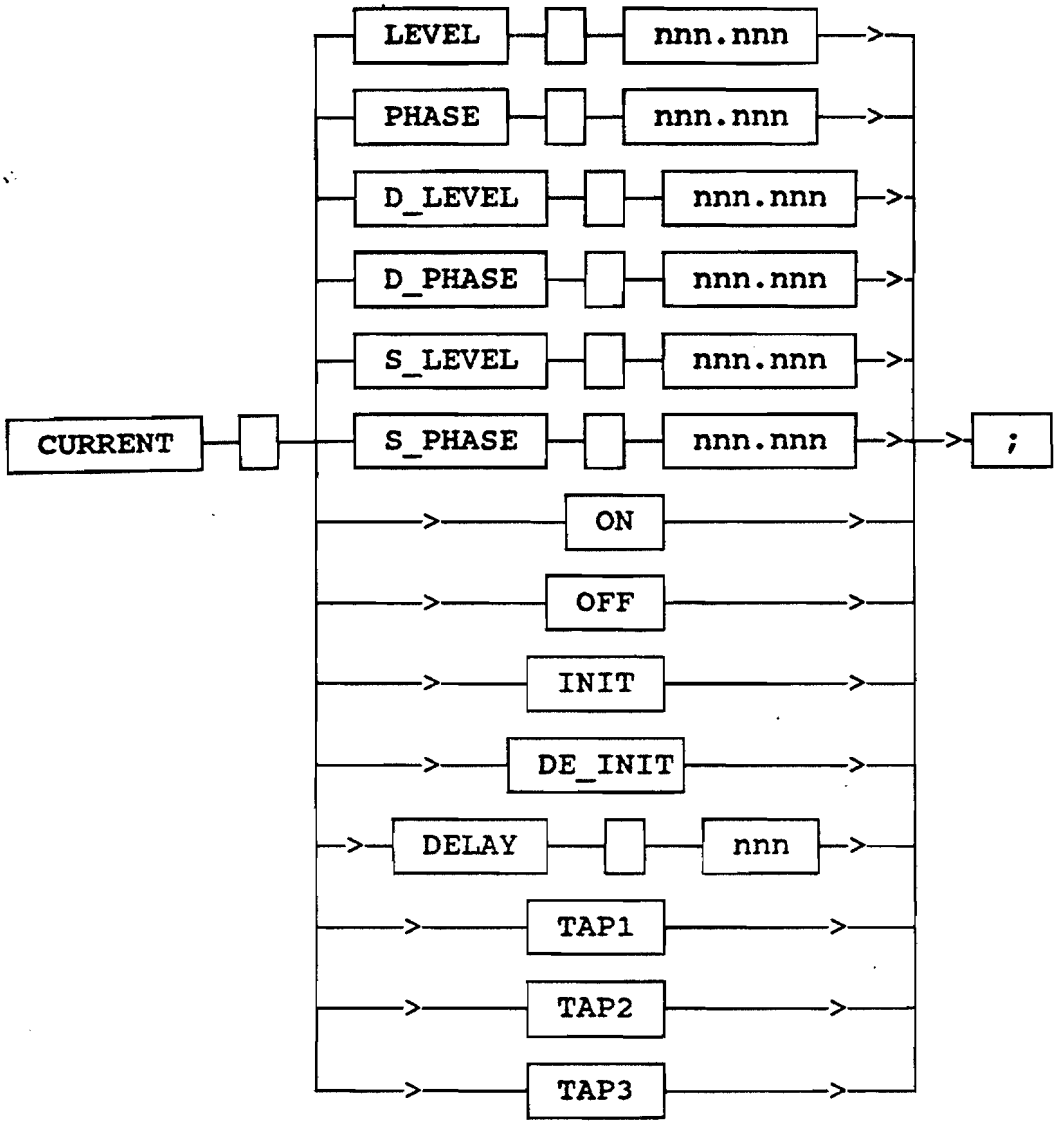
LEVEL	-	Amplitude and initial amplitude value for delta functions.
PHASE	-	Phase and initial phase value for delta functions.
D_LEVEL	-	Delta amplitude value.
D_PHASE	-	Delta phase value.
S_LEVEL	-	Step amplitude and final amplitude for delta functions.
S_PHASE	-	Step phase and final phase value for delta functions.
ON	-	On.
OFF	-	Off.
INIT	-	Initiate.
DE_INIT	-	De-initiate.
DELAY	-	Time delay value between delta updates in cycles (0-999).
TAP1	-	Select the EPOCH-I/10 internal 3.125 Ampere tap.
TAP2	-	Select the EPOCH-I/10 internal 12.50 Ampere tap.
TAP3	-	Select the EPOCH-I/10 internal 25.00 Ampere tap.

NOTE: For the EPOCH-II/20, the tap is set manually through the front panel output current terminals. The tap values for each range are as follows:

EPOCH-II/20 Tap	Rated Output Current
NULL	- invalid -
TAP1	10 Amperes
TAP2	15 Amperes
TAP3	40 Amperes
TAP4	50 Amperes
TAP5	100 Amperes
TAP6	170 Amperes

Table 3: EPOCH-II/20 Tap Keywords and Rated Output Values

Syntax format is as follows:



Typical commands would be as follows:

CURRENT LEVEL 12.34;	Sets current amplitude to 12.34 Amperes.
CURRENT ON;	Turns the current channel on.
CURRENT TAP3;	Sets current tap to 25.00 Ampere range for EPOCH-I/10. If EPOCH-II/20 mode, then the tap request is ignored.
CURRENT PHASE 60.0;	Sets the current phase to sixty degrees.
CURRENT S_LEVEL 20.0;	Sets the delta amplitude upper limit and the step amplitude to twenty Amperes.

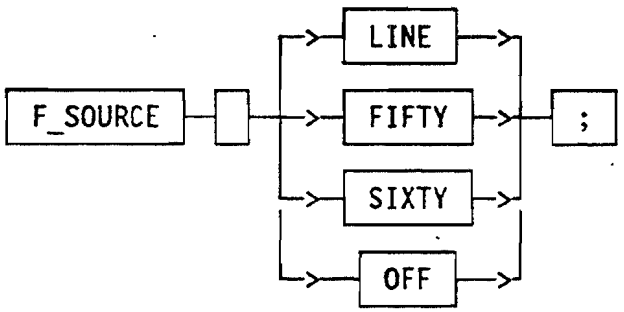
4.3 F_SOURCE

Allows the user to select the frequency source of the voltage and current outputs. The frequency can be selected such that it tracks the input line frequency or a fifty or sixty Hertz crystal oscillator.

Allowed action codes:

LINE - Frequency source tracks the input line frequency.
FIFTY - Frequency source is set to the fifty Hertz oscillator.
SIXTY - Frequency source is set to the sixty Hertz oscillator.
OFF - Frequency source is disabled - phasing reference mode must be in IDLE or SLAVE (see Section 3.7 for details on the PH_REF command description).

Syntax format is as follows:



Command Usage:

Note that the use of the frequency source is dependent on the Phase Reference mode. The frequency source is ENABLED ONLY for the MASTER mode Phase Reference. When the Phase Reference mode is SLAVE or IDLE, the frequency source is set to OFF. The OFF keyword will be sent to the controller when a SET? or RUN? query is issued for the frequency source when in SLAVE or IDLE Phase Reference mode.

F_SOURCE SIXTY; Will set the frequency source to sixty Hertz.

F_SOURCE LINE; Will set the frequency source to line tracking mode.

4.4 HARMONIC

Sets the harmonic output for the voltage and current channels. This function is independent of the state of the Phase Reference; harmonics may be used in the MASTER or SLAVE modes of operation.

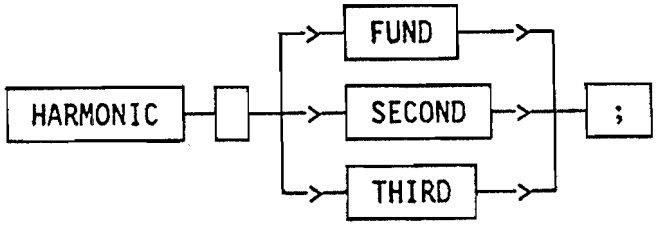
Allowed action codes:

FUND - The voltage and current outputs are at the same frequency as specified by the Frequency Source (MASTER mode) or the same as the frequency of the PHASE* signal input on the EPOCH-I/10 Interconnect Bus (SLAVE mode only).

SECOND - The outputs are at twice the frequency of the clock source (internal Frequency Source or the PHASE OUT* control line).

THIRD - The outputs are at three times the frequency of the clock source (internal Frequency Source or the PHASE OUT* control line).

Syntax format is as follows:



Command Usage:

HARMONIC FUND; Sets the outputs to fundamental mode.

HARMONIC THIRD; Sets the outputs to third harmonic mode.

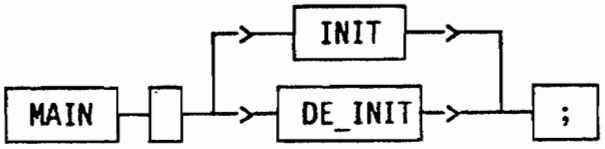
4.5 MAIN

Allows the initiation or de-initiation of all outputs in the local initiate mode. Note that a MASTER unit has direct control over all units in SLAVE mode - a MASTER unit can initiate or de-initiate the MAIN initiate control on all interconnected SLAVE units. Please refer to Section 3.7 for more details on the PH_REF command.

Allowed action codes:

INIT - Initiates all channels in the local initiate mode.
DE_INIT - De-initiates all channels in the local initiate mode.

Syntax format is as follows:



Command Usage:

MAIN INIT; Initiates all outputs in the local initiate mode.

MAIN DE_INIT; De-initiates all outputs in the local initiate mode.

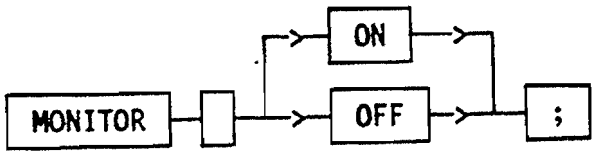
4.6 MONITOR

Allows the Continuity / Volts Applied Monitor horn to be turned on or off.

Allowed action codes:

ON - Enables the monitor horn.
OFF - Disables the monitor horn.

Syntax format is as follows:



Command Usage:

MONITOR OFF; Disables the monitor horn when the Continuity or Volts Applied inputs become active.

MONITOR ON; Enables the monitor horn when the Continuity or Volts Applied inputs become active.

4.7 PH_REF

This command controls the timing source. There are three modes; IDLE, MASTER and SLAVE. The EPOCH-I/10 Interconnect Bus also governs the Phase Reference when more than one unit is interconnected. The user has some degree of control, but the state of the Interconnect Bus has the highest priority.

Allowed action codes:

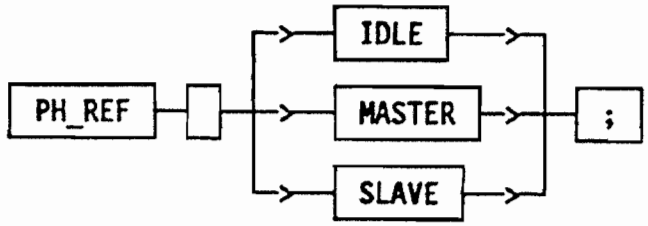
IDLE - This is the power-up default condition of the Phase Reference. When this mode is active, the front panel Phase Reference indicators are both unlit. The unit is ready to obey the state of the Interconnect Bus. There is no timing source activated - the frequency source is disabled and the MASTER* bus signal is inactive.

When two or more EPOCH-I/10 units are used, the MASTER unit may be set to IDLE mode by the switch input or by GPIB. All SLAVE units are then forced into IDLE mode also. If any SLAVE unit is forced to IDLE mode with the current and/or voltage channel on, a BUS ERROR condition results - error handling will shut down the amplifiers and inactivate SET? buffer command decoding.

SLAVE - This mode allows the EPOCH-I/10 to obtain its timing source from the Interconnect Bus. This mode may be activated from IDLE mode by the presence of a MASTER* unit. If an EPOCH-III Variable Frequency Test Set is residing on the bus, then all EPOCH-I/10 units activate SLAVE mode, with the EPOCH-III acting as MASTER. In addition, the state of the global initiate (MAIN) is controlled by the MASTER unit where the SLAVE unit follows the state of the MASTER unit's global initiate switch (MAIN).

MASTER - This mode allows the EPOCH-I/10 to generate its own timing references and act as a source of timing signals to all other EPOCH-I/10 units on the Interconnect Bus. Note that if any MASTER unit is forced into IDLE mode with the current and/or voltage channel on, a BUS ERROR condition results. An EPOCH-I/10 unit may be forced from IDLE to MASTER by pressing any switch or by a non-query GPIB command. Also, for any SLAVE unit interconnected, the state of the MASTER unit's initiate is also reflected in all SLAVE unit's global initiate switch (MAIN).

Syntax format is as follows:



Command Usage:

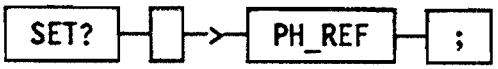
PH_REF MASTER; Sets the unit as a source of timing for the Interconnect Bus and enables the internal Frequency Source.

PH_REF IDLE; Sets the unit to IDLE mode from the MASTER mode. Note that this command has no effect if sent to a SLAVE unit. If this command is sent to the MASTER unit with other SLAVE units on the bus, ALL units will enter IDLE mode.

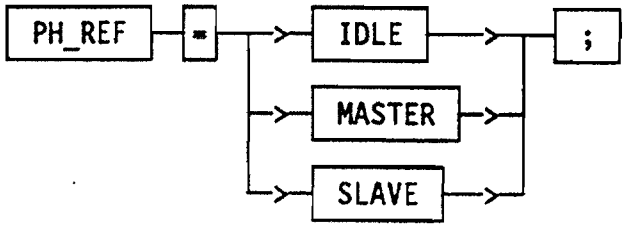
4.11.1.7 SET? PH_REF

This command allows the user to obtain the desired state setting for the phase reference control.

Syntax format is as follows:



Response format is as follows:



Command Usage:

SET? PH_REF; Queries the EPOCH-I/10 for the contents of the desired phase reference setting. If the master mode was forced by either a command, a switch action or a GPIB bus command, then the response would be as follows:

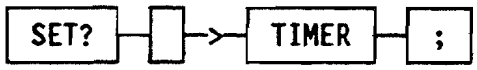
'PH_REF=MASTER;'

Note that the desired state can be changed by the hardware priority - for instance if two EPOCH-I/10 units were interconnected and both are in IDLE mode, when the MASTER unit is selected, the desired state on the MASTER unit is forced to MASTER; the desired state on the other unit is forced from IDLE to SLAVE by the interconnect bus priority.

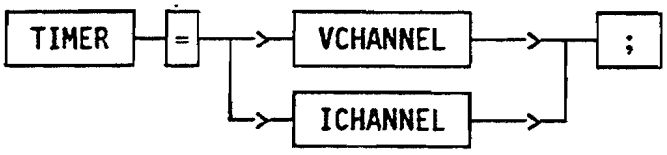
4.11.1.8 SET? TIMER

This command allows the user to obtain the desired state setting for the control channel timer start contacts.

Syntax format is as follows:



Response format is as follows:



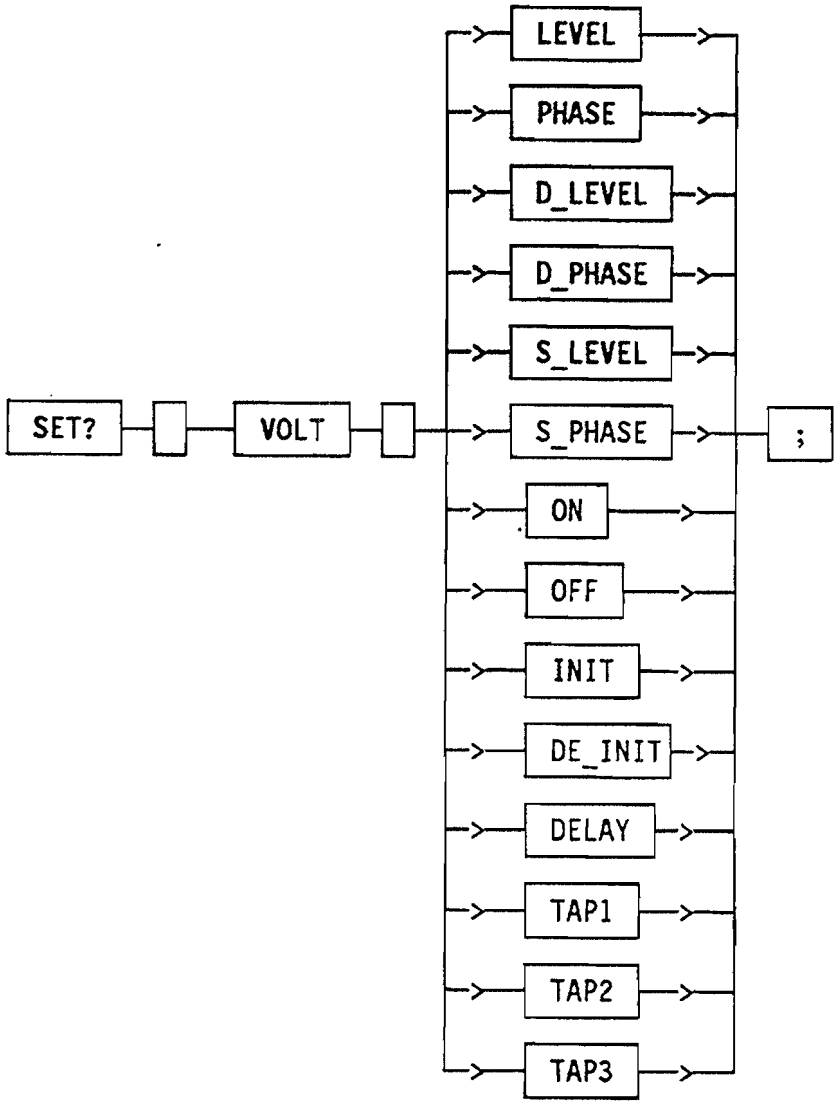
Command Usage:

SET? TIMER; Queries the EPOCH-I/10 for the contents of the desired timer start contacts setting. If a command for the timer start contacts is to be triggered off of the voltage channel, the response would be:

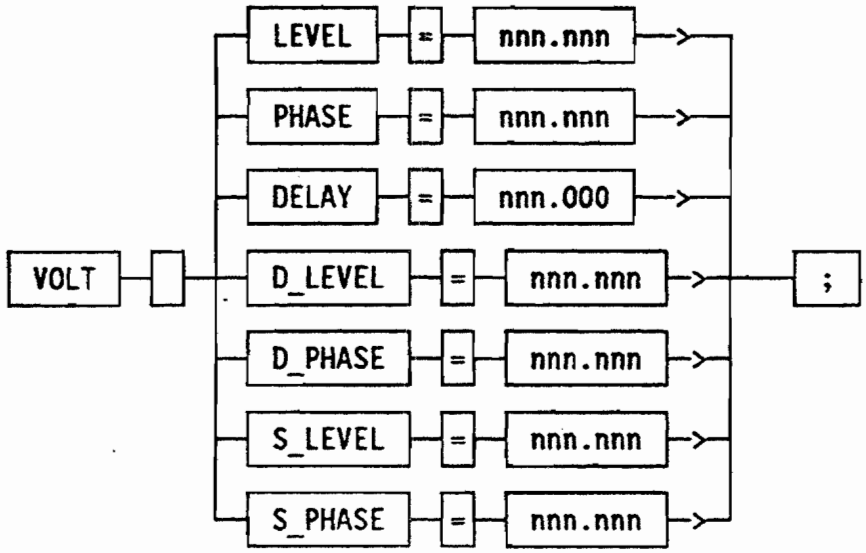
'TIMER=VCHANNEL;'

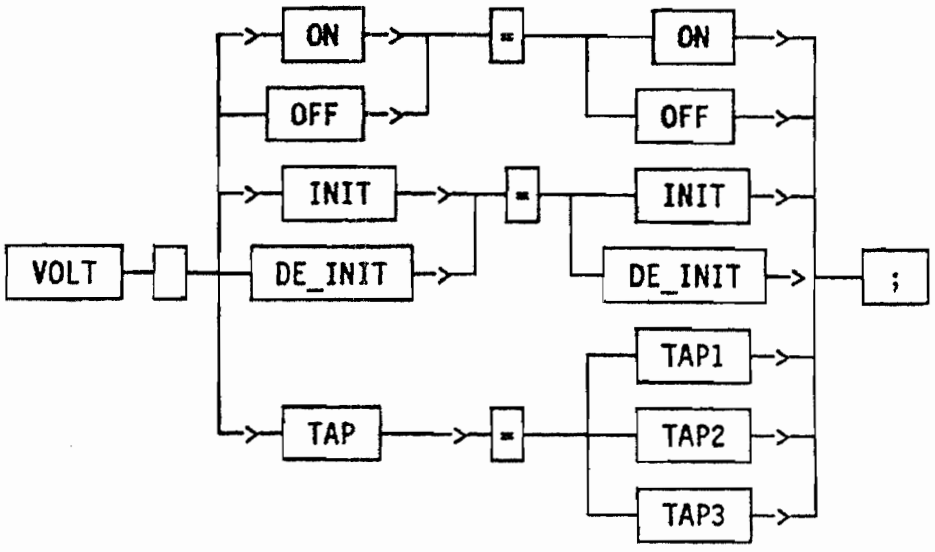
4.11.1.9 SET? VOLT

This command allows the user to obtain the desired state of any voltage channel variable. The syntax format is as follows:



Response format is as follows:




ON
OFF
INIT
DE_INIT
TAP
=
=
=
ON
OFF
INIT
DE_INIT
TAP1
TAP2
TAP3
VOLT
;

SET? VOLT S_LEVEL;	Queries the EPOCH-I/10 for the desired voltage channel final (step) value. If the step value was 110.0 Volts, the response would be: 'VOLT S_LEVEL= 110.000;'
SET? VOLT TAP1;	Queries the EPOCH-I/10 for the desired voltage channel tap setting. If the voltage tap was on the 300.0 Volt range, the response would be: 'VOLT TAP=TAP3;'
SET? VOLT OFF;	If the desired on/off state of the voltage channel was ON, the response to the Set? query would be: 'VOLT OFF=ON;'

4.11.2 RUN?

This command allows the parameters in the RUN? buffer to be read. The RUN? buffer contains the actual conditions of the output terminals and is used to obtain the present state of the EPOCH-I/10 or EPOCH-II/20.

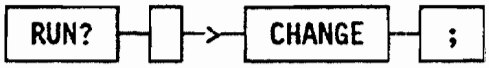
Allowed Action Codes:

All valid combinations of function and action codes.

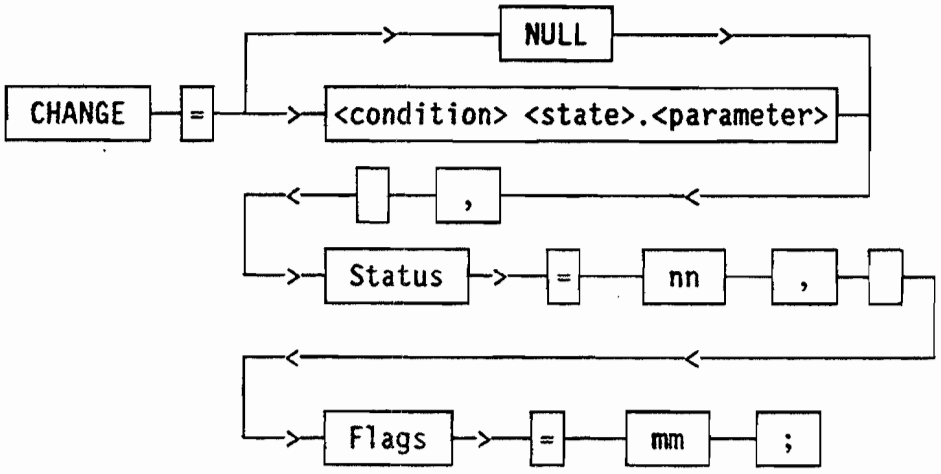
4.11.2.1 RUN? CHANGE

This command allows the user to obtain a listing of the programmed commands on the Execution Queue.

Syntax format is as follows:



Response format is as follows:

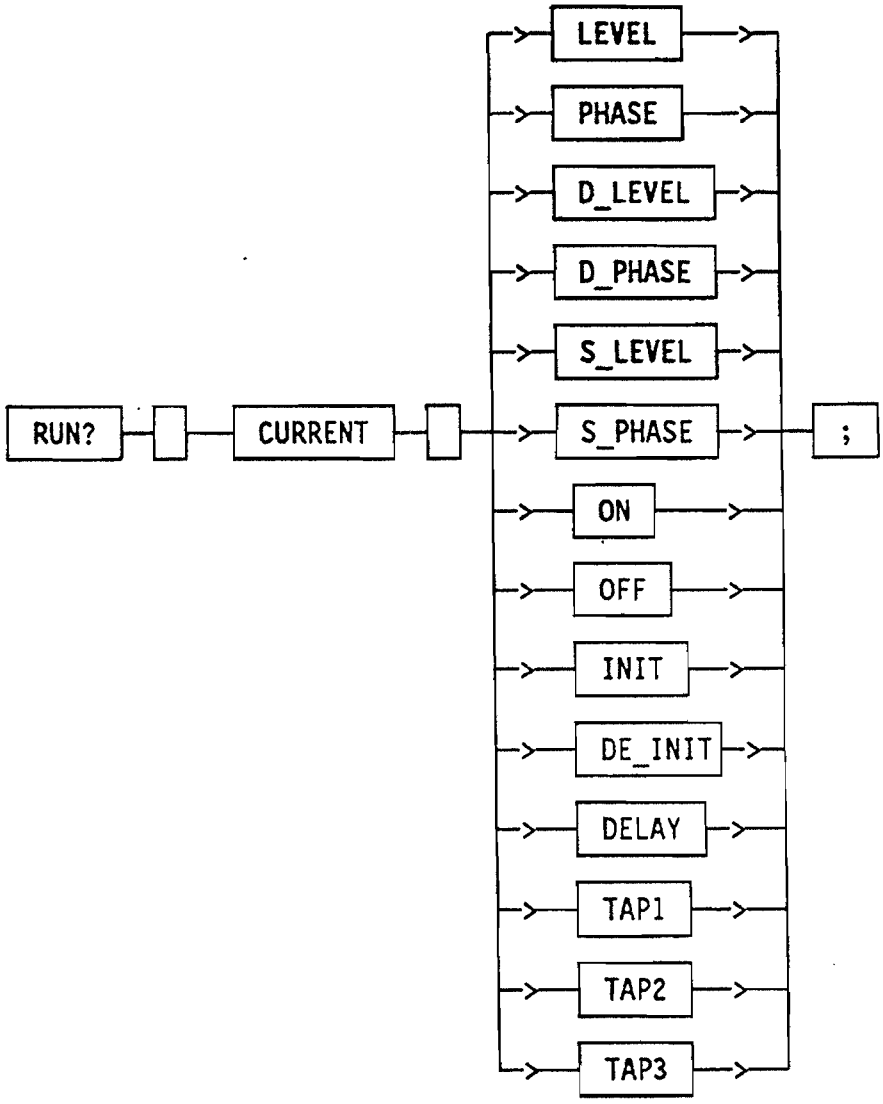


Command Usage:

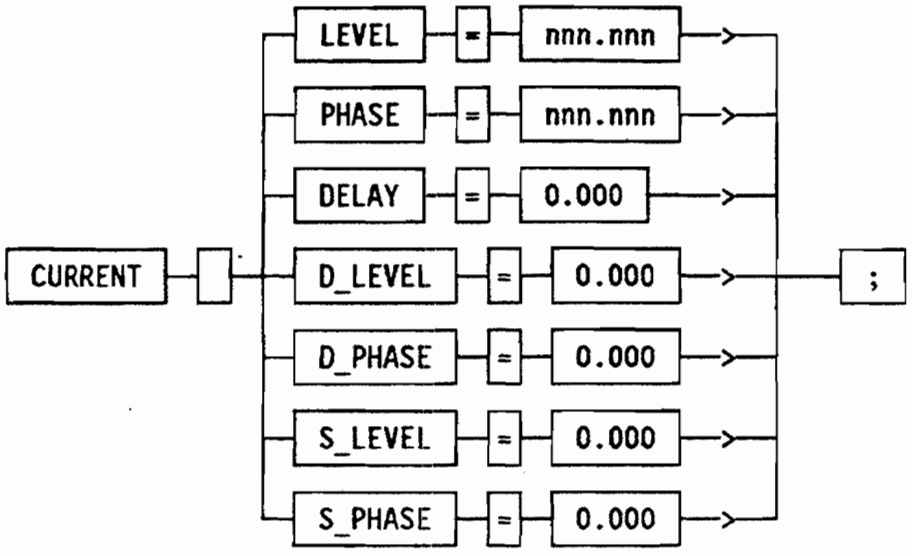
RUN? CHANGE;	Queries the EPOCH-I/10 for the contents of the NEXT instruction to be executed on the Execution Queue. If the next instruction was an unprogrammed one, the response would be 'CHANGE=NULL, STATUS=nn, FLAGS=mm;' where nn and mm correspond to the Binary Coded Decimal of the Queue STATUS and the FLAGS registers. (See Section 3.1 for more details on the Flags and Status registers).

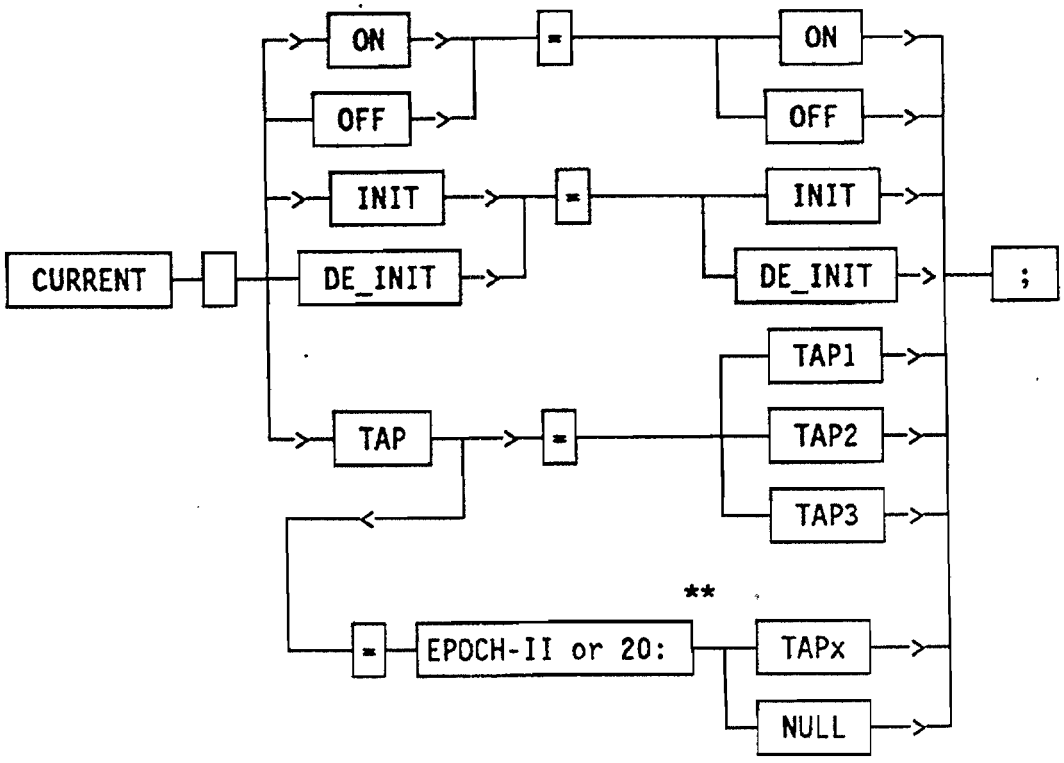
4.11.2.2 RUN? CURRENT

This command allows the user to obtain the output state of any current channel variable. The syntax format is as follows:



Response format is as follows:





** Note: EPOCH-II or 20 must be on-line for the special query - also note that both Set? and Run? Buffers share the same state because there can be no software forced tap changes on EPOCH-II/20. The tap value can range from one to six. If no tap has been selected, the 'NULL' value is assigned. See Table 3 for details.

RUN? CURRENT D_LEVEL; Queries the EPOCH-I/10 for the current channel incremental value. Since the Run? Buffer is **not** used for DELAY, D_LEVEL, D_PHASE, S_LEVEL and S_PHASE; the response is always zero:

'CURRENT D_LEVEL=0.000;'

RUN? CURRENT TAP1; Queries the EPOCH-I/10 for the output current channel tap setting. If the current tap was on the 12.5 Ampere range, the response would be:

'CURRENT TAP=TAP2;'
If the unit was in EPOCH-II/20 mode, and if the tap setting is on the 100 Ampere setting, the response would be:

'CURRENT TAP=EPOCH-II/20: TAP5;'

RUN? CURRENT ON;

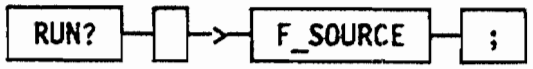
If the output on/off state of the current channel is OFF, the response to the Run? query would be:

'CURRENT ON=OFF;'

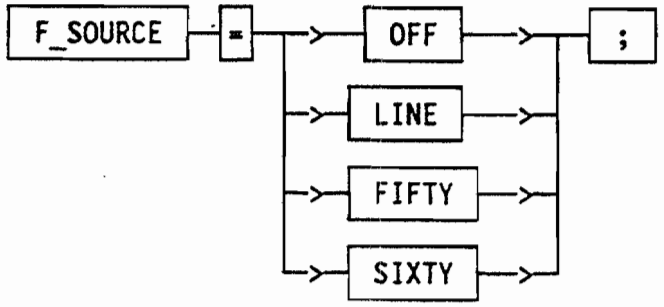
4.11.2.3 RUN? F_SOURCE

This command allows the user to obtain the output setting for the frequency source.

Syntax format is as follows:



Response format is as follows:



Command Usage:

RUN? F_SOURCE; Queries the EPOCH-I/10 for the frequency source output setting. If the fifty Hertz oscillator is the output source, (assuming MASTER mode of operation) then the response would be:

'F_SOURCE=FIFTY;'

If the phase reference mode is IDLE or SLAVE, then any query as to the output setting of the frequency source would be:

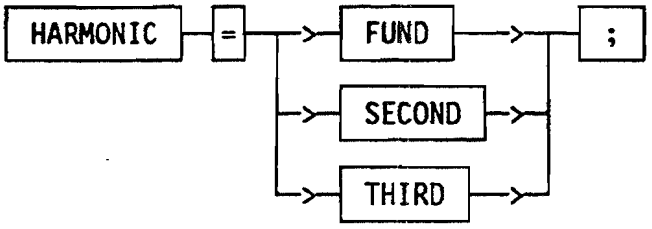
'F_SOURCE=OFF;'

4.11.2.4 RUN? HARMONIC

This command allows the user to obtain the output state setting for the harmonic control.

Syntax format is as follows:

Response format is as follows:



Command Usage:

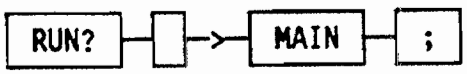
RUN? HARMONIC; Queries the EPOCH-I/10 for the output harmonic state. If the harmonic is set to fundamental, then the response would be:

'HARMONIC=FUND;'

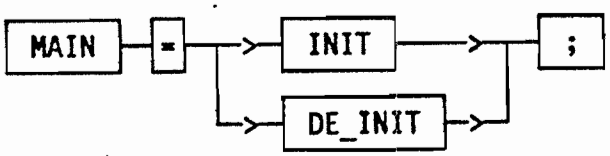
4.11.2.5 RUN? MAIN

This command allows the user to obtain the output state for the control channel (or main) initiate control.

Syntax format is as follows:



Response format is as follows:



Command Usage:

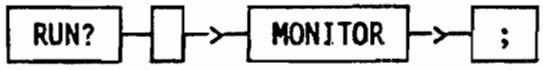
RUN? MAIN; Queries the EPOCH-I/10 for the output main initiate setting. If the state of the main initiate is initiate, then the response would be:

'MAIN=INIT;'

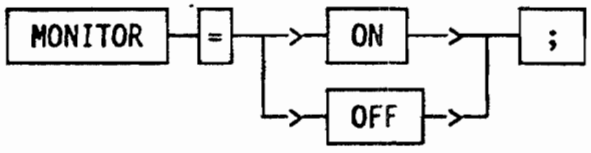
4.11.2.6 RUN? MONITOR

This command allows the user to obtain the output state of the monitor (or horn) control.

Syntax format is as follows:



Response format is as follows:



Command Usage:

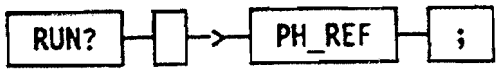
RUN? MONITOR; Queries the EPOCH-I/10 for the output state of the monitor (horn). If the state of the monitor is off, then the response would be:

'MONITOR=OFF;'

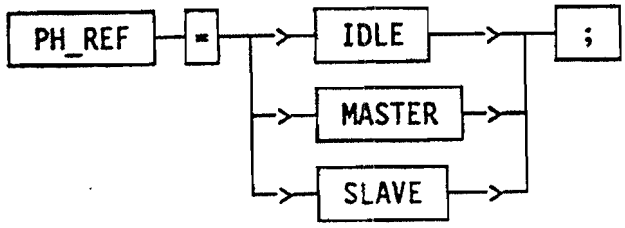
4.11.2.7 RUN? PH_REF

This command allows the user to obtain the output state setting of the phase reference control.

Syntax format is as follows:



Response format is as follows:



Command Usage:

RUN? PH_REF; Queries the EPOCH-I/10 for the output state of the phase reference control. If the IDLE mode was forced by either the interconnect bus, a switch action or a GPIB command, then the response would be as follows:

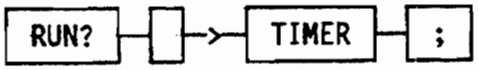
'PH_REF=IDLE;'

Note that the desired state can be changed by the hardware priority - for instance, if two EPOCH-I/10 units were interconnected and both are in IDLE mode, when the MASTER unit is selected, the desired state on the MASTER unit is forced to MASTER; the desired state on the other unit is forced from IDLE to SLAVE by the interconnect bus priority.

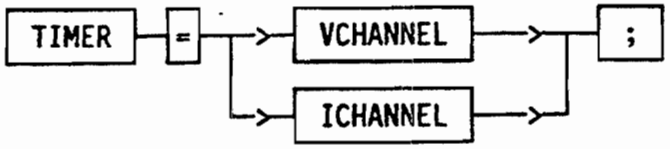
4.11.2.8 RUN? TIMER

This command allows the user to obtain the output state setting for the control channel timer start contacts.

Syntax format is as follows:



Response format is as follows:



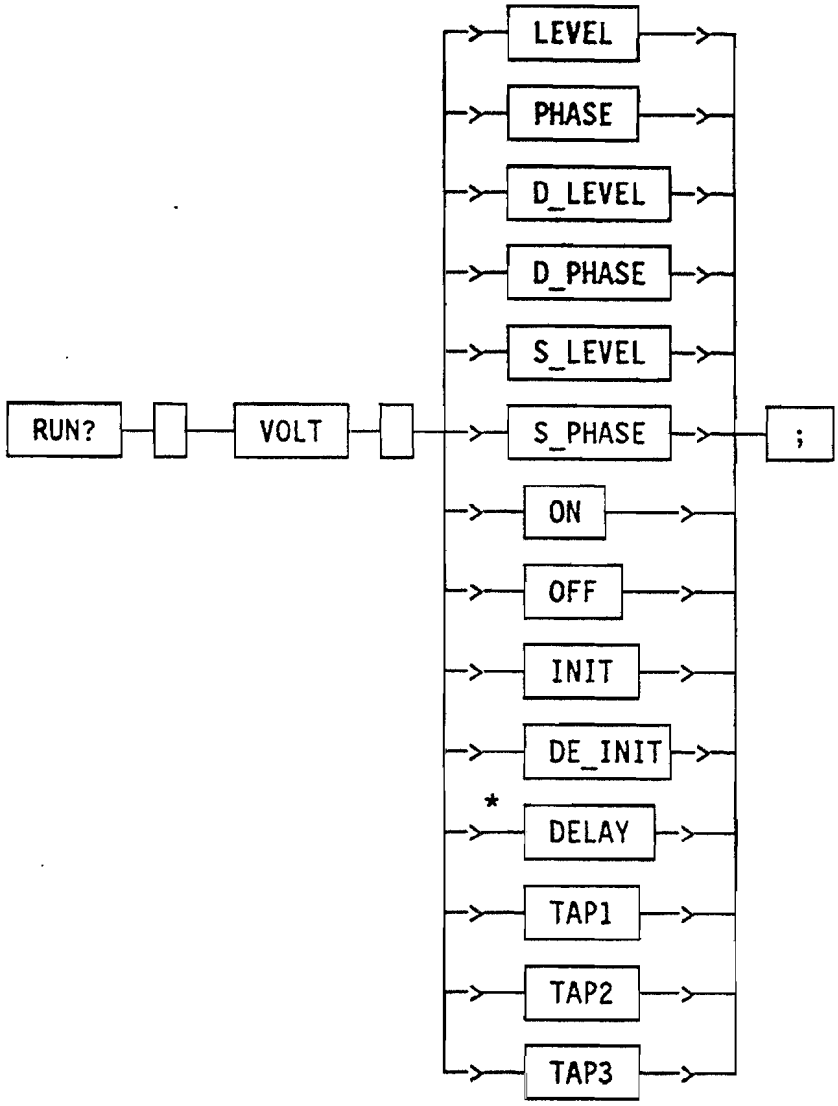
Command Usage:

RUN? TIMER; Queries the EPOCH-I/10 for the output state for the timer start control. If the timer start contacts are to be triggered off of the current channel, the response would be:

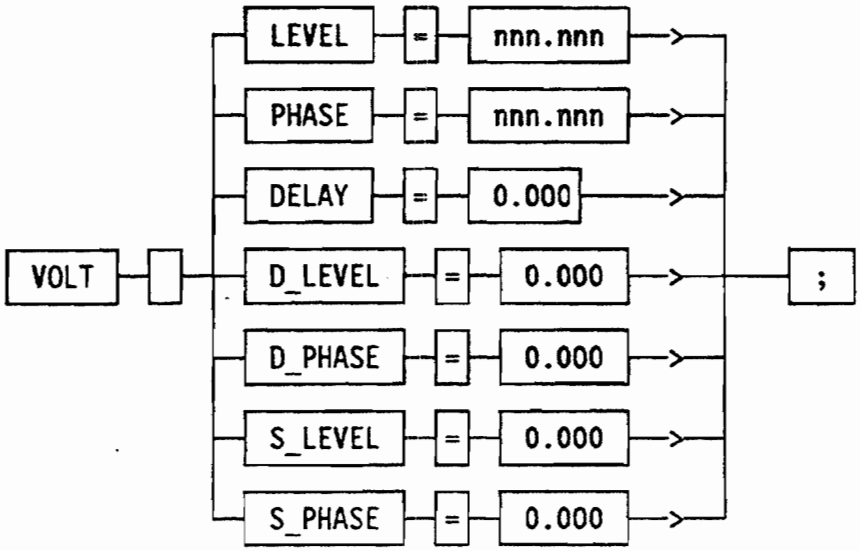
'TIMER=ICHANNEL;'

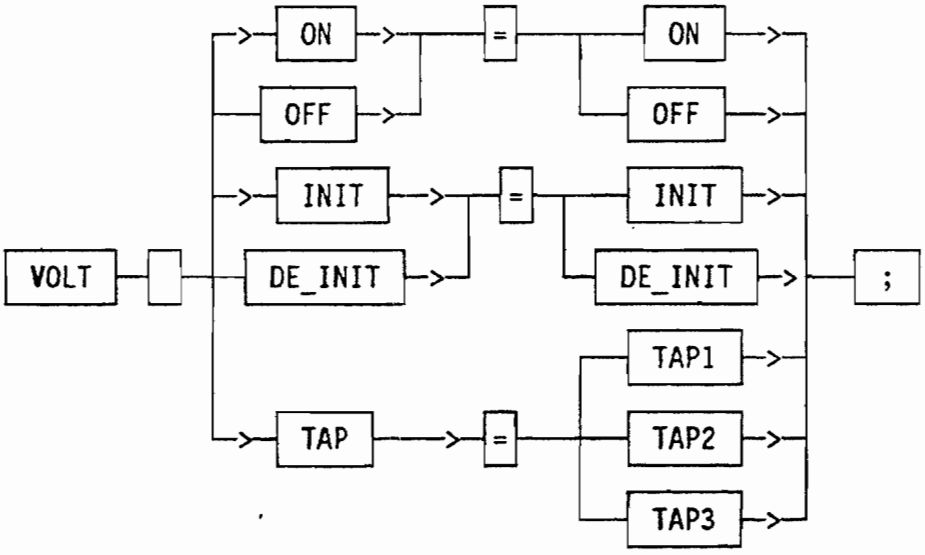
4.11.2.9 RUN? VOLT

This command allows the user to obtain the output state of any voltage channel variable. The syntax format is as follows:



Response format is as follows:





Command Usage:

RUN? VOLT DELAY; Queries the EPOCH-I/10 for the actual voltage channel delay value in cycles. Since the Run? Buffer does not reflect the state of the DELAY, D_LEVEL, D_PHASE, S_LEVEL and S_PHASE values, the response is always a zero:

'VOLT DELAY=0.000;'

RUN? VOLT TAP1; Queries the EPOCH-I/10 for the output voltage channel tap setting. If the voltage tap was on the 150.0 Volt range, the response would be:

'VOLT TAP=TAP2;'

RUN? VOLT ON; If the output on/off state of the voltage channel was OFF, the response to the Set? query would be:

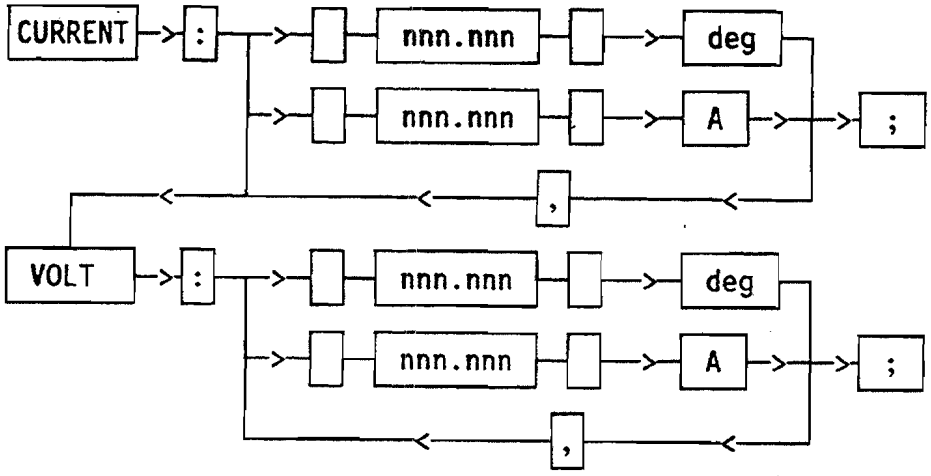
'VOLT ON=OFF;'

4.11.3 STATUS?

This command transmits the output conditions that were saved by the REPORT command (see Section 4.1.4.1). The user is notified when the output conditions are stored by the EPOCH-I/10 asserting Service Request (SRQ) true. The Controller's interrupt service routine may distinguish the difference between any serious error messages and the notification by noting the Serial Poll data. Errors will have the 'Error' bit set to logic one, where the REPORT notification sets the 'Error' bit to logic zero (see Section 4.11.4 for the Serial Poll bit definitions).

Syntax format is as follows:

The response from the EPOCH-I/10 is as follows:



Command Usage:

STATUS?; A typical response from the EPOCH-I/10 would be as follows:

'CURRENT: 5.000 A, 60.0 deg, VOLT: 270.0 V, 0.0 deg;'.

This is assuming that the <state> command was a '10.15' with respect to the command and its parameter. If the <state> command was a '10.12', then the status response would be:

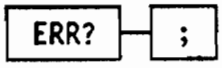
'VOLT: 270.0 V, 0.0 deg;'

4.11.4 ERR?

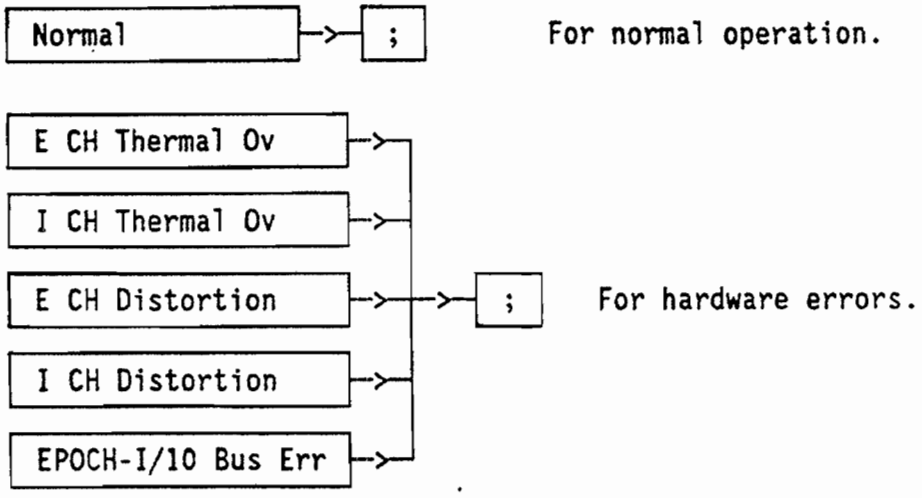
This command allows the operator to query the EPOCH-I/10 for an error status. Note that the EPOCH-I/10 sends an error message on the FIRST occurrence of an error to prevent software lockup on an error condition. This method also allows multiple error messages to be issued for a given condition.

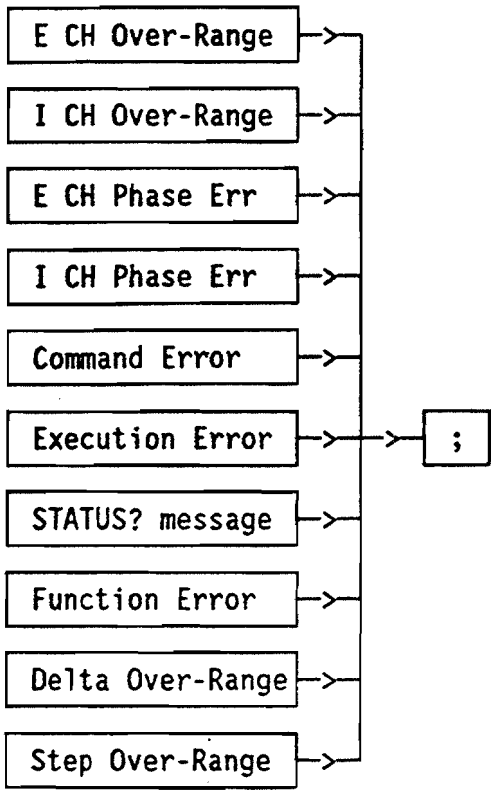
NOTE: The hardware error messages (Distortion, Thermal Overload and Bus Error) do not issue a Service Request in the LOCAL mode.

Syntax format is as follows:



Response format is as follows:





For software / programming errors.

4.11.4.1 GPIB Serial Poll / Service Request

The ERR? query is useful in Service Request (SRQ) Interrupt software. On the first occurrence of an error state, such as thermal overload, the EPOCH-I/10 forces the GPIB SRQ signal true. The SRQ signal remains active until the Controller responds with a serial poll on the GPIB. The error number is coded in the lower four bits, where any non-zero code reflects an error condition. The exception to this rule is the STATUS? message pending code. The purpose of this code is to notify the user that the output conditions have been read and latched into a GPIB accessible buffer (see Section 4.1.3.1 for details on the REPORT command). Bit six denotes SRQ activity and bit four denotes an error condition by a logic one state. Note that all Errors are reported via the GPIB only in GPIB Control mode. The 'ERR?;' query is valid when the Controller receives a Service Request. The byte of data obtained via the serial poll is as follows:

Bit	Description
7	Unused (always set to zero).
6	Unit is requesting service.
5	Error condition present.
4	Indicates State of MONITOR. "1" = CLOSED, "0" = OPEN. (*).
3-0	Error code (in decimal): 0 Normal 1 E Channel Over-range 2 I Channel Over-range 3 E Channel Thermal Overload 4 I Channel Thermal Overload 5 E Channel Distortion 6 I Channel Distortion 7 E Channel Phase Error 8 I Channel Phase Error 9 Command Error 10 Execution Error 11 STATUS? Message Pending 12 Function Error 13 Bus Error 14 Delta Over-range 15 Step Over-range

(*) On versions up to and including 2.41, Bit 4 is unused (always set to zero).

4.11.4.2 Hardware Errors

There are five error conditions which disable the SET? Buffer / RUN? Buffer state comparitor. These error conditions force a state change in hardware - usually zeroing the level or turning the outputs off. These errors are as follows:

Error	Explanation	Action
I Ch Thermal Ov	The current channel power amplifier is in thermal overload. The display indicates all E's. The amplifier output should be at zero.	Leave the unit on - wait for the overload condition to clear. When the displays now read zeroes, then the thermal overload condition has cleared. The user must now issue a 'CHANGE GPIB 70;' command if in GPIB operation.
E Ch Thermal Ov	The voltage channel power amplifier is in thermal overload. The display will show all E's. The amplifier output should be at zero.	Leave the unit on - wait for the overload condition to clear. When the displays now read zeroes, then the thermal overload condition has cleared. The user must now issue a 'CHANGE GPIB 70;' command if in GPIB operation.
I Ch Distortion	The current channel cannot drive the load on its output terminals.	For manual mode operation, a tap change will be effected if the level is where the upper or lower tap can provide better compliance. If level is in range, the output is shut down. For GPIB operation, the outputs are shut down and the operator must issue a 'CHANGE GPIB 70.0;' to resume SET? buffer control. For EPOCH-II/20, no tap change will result.

E Ch Distortion	The voltage channel cannot drive the load present on the output terminals.	For manual mode, a tap change will be effected if the tap is where the upper or lower tap can provide better current. If level is in range, output is shut down. For GPIB operation, the outputs are shut down and the operator must issue a 'CHANGE GPIB 70.0;' to restore SET? buffer control.
Bus Error	A SLAVE unit has lost timing signals from the EPOCH Interconnect Bus while the amplifiers were on.	All outputs are shut down. For GPIB mode, the operator must send a 'CHANGE GPIB 70.0;' command to resume SET? buffer control.

4.11.4.3 Distortion Alarm

For the distortion alarm, there is a single timing element, the acknowledge period. The acknowledge period is based on sinusoidal cycles and is defined as the time in cycles for distortion to be continually active before the software will recognize it as a hardware over-drive condition. It is at this point where the outputs are forced off. The alarm timeout is defined for EPOCH-I/10 as the period of time before the output will be shut down by the control software. When the output is turned off by distortion acknowledge, the queue is forced into HALT mode, the Set? Buffer comparitor is disabled and any delta mode is stopped.

In EPOCH-I/10, the tap can change under software control if the following conditions are met:

1. Manual mode of operation.

2. The tap lock switch is in the OFF position.

3. The level must be under the lower tap change limit or above the upper tap change limit for that particular tap. For example, if the 12.50 Ampere tap is selected, and the current level is at 3.00 Amperes, the tap will change to the 3.125 Ampere tap when a distortion timeout occurs. This is because the level (3.00) is below the lower limit of 3.12 Amperes for the 12.50 Ampere tap. (See Section 5.0 for level data)

4. Note that a distortion controlled tap change can only happen once - this is to avoid an oscillating tap change state.

5. The output will be turned back on by the software in the originating mode; either ON or INITIATE, after the tap change has been finished.

For EPOCH-II/20 operation, the distortion alarm is internal to the EPOCH-II/20 unit. The acknowledge time is set by the software to be four cycles. If the acknowledge time is met, then the EPOCH-II/20 will shut down locally. When the distortion acknowledge time is met, the current channel on/off indicator will be turned off. The alarm will sound (with the output OFF) for approximately one-half second. The alarm rate is significantly faster than the alarm on EPOCH-I/10 current channel. This mechanism enables the user to get early notification of problems. The GPIB error message, the queue HALT and the Set? Buffer disable will occur soon as the acknowledge time is met.

4.11.4.4 Other Errors

The other errors are syntax and numeric range error conditions. Note that for numeric range errors, the SET? buffer is not disabled. The numeric and syntax errors are as follows:

Error	Explanation	
I Ch Over-Range	A level value exceeds the maximum allowable value for an EPOCH-I/10 or EPOCH-II/20 current tap.	The Set? level is overwritten with the maximum value.
E Ch Over-Range	A level value exceeds the maximum allowable value for a voltage tap.	The angle is adjusted for the range 0.0 < = angle < 360.0 degrees.
I Ch Phase Err	A phase value exceeds the range 0.0 < = angle < 720.0 degrees. Any sign is ignored.	The angle is adjusted for the range 0.0 < = angle < 360.0 degrees.
E Ch Phase Err	A phase value exceeds the range 0.0 < = angle < 720.0 degrees. Any sign is ignored.	The D_LEVEL argument is set to zero.
Delta Over-Range	A D_LEVEL argument has exceeded the maximum allowable range for a particular tap.	The S_LEVEL argument is set to zero.
Step Over-Range	A S_LEVEL argument has exceeded the maximum allowable range for a particular tap.	No action taken - the command is ignored.
Command Error	The command was incorrect or as misspelled.	No action taken -
Function Error	The function code Action	the command is ignored.
	The Set? level is overwritten with the maximum value. was followed by an illegal action code.	

Execution Error	The Conditional Execution Queue attempted to process an illegal command. The queue was not programmed.	Execution is halted. Execution Queue attempted to process an illegal command. The queue was not programmed.

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5.0 Software Version 1.3 and 2.40 Compatibility

There are several major differences between EPOCH software versions 1.3 and 2.40*. They listed as follows:

- The distortion alarm for the current channel has twenty cycles of acknowledge time in the new version, the old version has 120 cycles. The distortion alarm for the voltage channel has sixty cycles of acknowledge time in the new version, the version 1.3 has 120 cycles. There is no way to release the alarm once it is tripped for version 2.40 and up, since the output is already off when the alarm sounds. In version 1.3, it takes twelve cycles of distortion free output to recover from distortion.

- The EPOCH-I/10 voltage and current channels have been changed as to the maximum allowable value. The changes are listed below:

Tap	Version 1.3	Version 2.40 and up
150 V	240.0	155.0
300 V	400.0	310.0
12.5 A	30.00	20.00
25 A	40.00	31.00

- The queue "Pause Execution" command, 'CHANGE GPIB 83;', no longer pauses the delta function, since the user may need to keep the delta mode active. If the user requires a temporary halt to the delta function, this may be done by using the 'CHANGE GPIB 9.nn;' command and then issuing a 'CHANGE GPIB 8.nn;' command (see section 4.1.3.1 for further information on the programmable queue commands).

- The on/off control algorithm has been revised to accommodate dual channel turn on and turn off for both synchronous and asynchronous modes. Note that the initiate mode under manual control causes the outputs to turn on synchronously with the phase reference. For a summary of changes, please refer to Table 4.

- For version 2.42 a serial poll, on the GPIB, was added for a query of the MONITOR binding posts, see 4.11.4.1 for details.

(*)Most EPOCH-I's should be updated to version 2.40, and many have versions 2.41. Some EPOCH-I's may have version 2.42 (for use with MasterTest™ software). All Model EPOCH-10's start with Version 2.42.

Operational State	Off-to-On Mode
EPOCH-I/10 Manual On/Off	Asynchronous On
EPOCH-I/10 Manual Initiate	Synchronous On
EPOCH-II/20 Manual On/Off	Asynchronous On
EPOCH-II/20 Manual Initiate	Synchronous On
EPOCH-I/10/II/20 GPIB:	
VOLT ON;	Synchronous On
CURRENT ON;	Synchronous On
VOLT INIT;	Synchronous On
CURRENT INIT;	Synchronous On
Queue — GET:	
Off-to-On	Asynchronous On
Off-to-Step	Asynchronous On
Off-to-Delta	Synchronous On
M_OPEN:	
Off-to-On	Asynchronous On
Off-to-Step	Asynchronous On
Off-to-Delta	Synchronous On
M_CLOSE	
Off-to-On	Asynchronous On
Off-to-Step	Asynchronous On
Off-to-Delta	Synchronous On
EVENT:	
Off-to-On	Synchronous On
Off-to-Step	Synchronous On
Off-to-Delta	Synchronous On
ZERO_PH:	
Off-to-On	Synchronous On
Off-to-Step	Synchronous On
Off-to-Delta	Synchronous On
GPIB:	
Off-to-On	Synchronous On
Off-to-Step	Synchronous On
Off-to-Delta	Synchronous On
Distortion:	
Manual Off-to-On	Asynchronous On
Manual Off-to-Initiate	Synchronous On
Interconnect Bus:	
Manual Slave Initiate	Synchronous On
GPIB Slave Initiate	Synchronous On

Table 4: Off-to-On Modes for Various Operational States

5.1 Queue Command Set Differences

The queue command set has been restructured. In version 2.42, the parameter (current and voltage, phase and amplitude) is separated from the <state> identifier. This allows for much greater programming efficiency, particularly in the Execution Queue. (See Section 4.1.3.1 for specific details on version 2.42 commands.)

The correspondence between version 1.3 and version 2.42 for the programmable queue commands are as follows:

5.1.1 Non-Delta Commands

Version 1.3	Version 2.42	Comments
CHANGE <cond> 0;	CHANGE <cond> 0.1;	Current channel ON to OFF.
CHANGE <cond> 10;	CHANGE <cond> 0.4;	Voltage channel ON to OFF.
CHANGE <cond> 0; CHANGE <cond> 10;	CHANGE <cond> 0.5;	Current and voltage channel ON to OFF.
CHANGE <cond> 1;	CHANGE <cond> 1.1;	Current channel OFF to ON.
CHANGE <cond> 11;	CHANGE <cond> 1.4;	Voltage channel OFF to ON.
CHANGE GPIB 72; CHANGE <cond> 2;	CHANGE <cond> 2.1;	Current channel amplitude OFF to STEP.
CHANGE GPIB 72; CHANGE <cond> 12;	CHANGE <cond> 2.4;	Voltage channel amplitude OFF to STEP.
CHANGE GPIB 72; CHANGE <cond> 2; CHANGE <cond> 12;	CHANGE <cond> 2.5;	Current and voltage channel amplitude OFF to STEP.
CHANGE GPIB 73; CHANGE <cond> 2;	CHANGE <cond> 2.2;	Current channel phase OFF to STEP.
CHANGE GPIB 73; CHANGE <cond> 12;	CHANGE <cond> 2.8;	Voltage channel phase OFF to STEP.

CHANGE GPIB 73; CHANGE <cond> 2; CHANGE <cond> 12;	CHANGE <cond> 2.10;	Current and voltage channel phase OFF to STEP.
CHANGE GPIB 74; CHANGE <cond> 2;	CHANGE <cond> 2.3;	Current channel amplitude and phase OFF to STEP.
CHANGE GPIB 74; CHANGE <cond> 12;	CHANGE <cond> 2.12;	Voltage channel amplitude and phase OFF to STEP.
CHANGE GPIB 74; CHANGE <cond> 2; CHANGE <cond> 12;	CHANGE <cond> 2.15;	Current and voltage channel amplitude and phase OFF to STEP.
CHANGE <cond> 3; ** NOTE ** Version 1.3: This command will work if any channel's phase or amplitude has been previously stepped.	CHANGE <cond> 3.3;	Current channel amplitude or phase STEP to OFF.
CHANGE <cond> 13; ** NOTE ** Version 1.3: This command will work if any channel's phase or amplitude has been previously stepped.	CHANGE <cond> 3.10;	Voltage channel amplitude or phase STEP to OFF.
CHANGE <cond> 3; CHANGE <cond> 13;	CHANGE <cond> 3.15;	Current and voltage channel amplitude or phase STEP to OFF.
CHANGE GPIB 72; CHANGE <cond> 4;	CHANGE <cond> 4.1;	Current channel amplitude ON to STEP.
CHANGE GPIB 72; CHANGE <cond> 14;	CHANGE <cond> 4.4;	Voltage channel amplitude ON to STEP.
CHANGE GPIB 72; CHANGE <cond> 4; CHANGE <cond> 14;	CHANGE <cond> 4.5;	Current and voltage channel amplitude ON to STEP.
CHANGE GPIB 73; CHANGE <cond> 4;	CHANGE <cond> 4.2;	Current channel phase ON to STEP.
CHANGE GPIB 73; CHANGE <cond> 14;	CHANGE <cond> 4.8;	Voltage channel phase ON to STEP.

CHANGE GPIB 73; CHANGE <cond> 4; CHANGE <cond> 14;	CHANGE <cond> 4.10;	Current and voltage channel phase ON to STEP.
CHANGE GPIB 74; CHANGE <cond> 4;	CHANGE <cond> 4.3;	Current channel amplitude and phase ON to STEP.
CHANGE GPIB 74; CHANGE <cond> 14;	CHANGE <cond> 4.12;	Voltage channel amplitude and phase ON to STEP.
CHANGE GPIB 74; CHANGE <cond> 4; CHANGE <cond> 14;	CHANGE <cond> 4.15;	Current and voltage channel amplitude and phase ON to STEP.
CHANGE <cond> 5; ** NOTE ** Version 1.3: This command will work if any channel's phase or amplitude has been previously stepped.	CHANGE <cond> 5.3;	Current channel amplitude or phase STEP to ON.
CHANGE <cond> 15; ** NOTE ** Version 1.3: This command will work if any channel's phase or amplitude has been previously stepped.	CHANGE <cond> 5.10;	Voltage channel amplitude or phase STEP to ON.
CHANGE <cond> 5; CHANGE <cond> 15;	CHANGE <cond> 5.15;	Current and voltage channel amplitude or phase STEP to ON.

5.1.2 Delta Commands - SWING and ROLL inactive

This section details the DELTA function commands. Note that this section does not use the SWING or ROLL options for the DELTA. In other words, if the command is OFF/ON to DELTA, the output will stop incremental changes on reaching the final value (S_LEVEL or S_PHASE).

CHANGE GPIB 72; CHANGE GPIB 76; CHANGE GPIB 78; CHANGE <cond> 6;	CHANGE <cond> 6.1;	Current channel amplitude OFF to DELTA.

** NOTE ** Version 1.3: If the voltage channel amplitude has a non-zero delta, the voltage channel will begin to delta - even though the output may be off.

CHANGE GPIB 72; CHANGE GPIB 76; CHANGE GPIB 78; CHANGE <cond> 16;	CHANGE <cond> 6.4;	Voltage channel amplitude OFF to DELTA.

** NOTE ** Version 1.3: If the current channel amplitude has a non-zero delta, the voltage channel will begin to delta - even though the output may be off.

CHANGE GPIB 72; CHANGE GPIB 76; CHANGE GPIB 78; CHANGE <cond> 6; CHANGE <cond> 16;	CHANGE <cond> 6.5;	Current and voltage channel amplitude OFF to DELTA.

CHANGE GPIB 73; CHANGE GPIB 76; CHANGE GPIB 78; CHANGE <cond> 6;	CHANGE <cond> 6.2;	Current channel phase OFF to DELTA.

** NOTE ** Version 1.3: If the voltage channel phase has a non-zero delta the voltage phase channel will begin to delta -even though

the output may be off.

CHANGE GPIB 73; CHANGE GPIB 76; CHANGE GPIB 78; CHANGE <cond> 16;	CHANGE <cond> 6.8;	Voltage channel phase OFF to DELTA.

** NOTE ** Version 1.3: If the current channel phase has a non-zero delta, the current channel phase will begin to delta -even though the output may be off.

CHANGE GPIB 73; CHANGE GPIB 76; CHANGE GPIB 78; CHANGE <cond> 6; CHANGE <cond> 16;	CHANGE <cond> 6.10;	Current and voltage channel phase OFF to DELTA.
CHANGE GPIB 74; CHANGE GPIB 76; CHANGE GPIB 78; CHANGE <cond> 6;	CHANGE <cond> 6.3;	Current channel amplitude and phase OFF to DELTA.
CHANGE GPIB 74; CHANGE GPIB 76; CHANGE GPIB 78; CHANGE <cond> 16;	CHANGE <cond> 6.12;	Voltage channel amplitude and phase OFF to DELTA.
CHANGE GPIB 74; CHANGE GPIB 76; CHANGE GPIB 78; CHANGE <cond> 6; CHANGE <cond> 16;	CHANGE <cond> 6.15;	Current / voltage channel phase and amplitude OFF to DELTA.
CHANGE <cond> 7;	CHANGE <cond> 7.3;	Current channel amplitude or phase DELTA to OFF.
CHANGE <cond> 17;	CHANGE <cond> 7.12;	Voltage channel amplitude or phase DELTA to OFF.

CHANGE GPIB 72; CHANGE GPIB 76; CHANGE GPIB 78; CHANGE <cond> 8;	CHANGE <cond> 8.1;	Current channel amplitude ON to DELTA.
** NOTE ** Version 1.3: If the voltage channel amplitude has a non-zero delta, the voltage channel will begin to delta - even though the output may be off.		
CHANGE GPIB 72; CHANGE GPIB 76; CHANGE GPIB 78; CHANGE <cond> 18;	CHANGE <cond> 8.4;	Voltage channel amplitude ON to DELTA.
** NOTE ** Version 1.3: If the current channel amplitude has a non-zero delta, the voltage channel will begin to delta - even though the output may be off.		
CHANGE GPIB 72; CHANGE GPIB 76; CHANGE GPIB 78; CHANGE <cond> 8; CHANGE <cond> 18;	CHANGE <cond> 8.5;	Current and voltage channel amplitude ON to DELTA.
CHANGE GPIB 73; CHANGE GPIB 76; CHANGE GPIB 78; CHANGE <cond> 8;	CHANGE <cond> 8.2;	Current channel phase ON to DELTA.
** NOTE ** Version 1.3: If the voltage channel phase has a non-zero delta the voltage phase channel will begin to delta -even though the output may be off.		

CHANGE GPIB 73; CHANGE GPIB 76; CHANGE GPIB 78; CHANGE <cond> 18;	CHANGE <cond> 8.8;	Voltage channel phase ON to DELTA.
** NOTE ** Version 1.3: If the current channel phase has a non-zero delta, the current channel phase will begin to delta -even though the output may be off.		
CHANGE GPIB 72; CHANGE GPIB 76; CHANGE GPIB 78; CHANGE <cond> 8; CHANGE <cond> 18;	CHANGE <cond> 8.10;	Current and voltage channel phase ON to DELTA.
CHANGE GPIB 74; CHANGE GPIB 76; CHANGE GPIB 78; CHANGE <cond> 8;	CHANGE <cond> 8.3;	Current channel amplitude and phase ON to DELTA.
CHANGE GPIB 74; CHANGE GPIB 76; CHANGE GPIB 78; CHANGE <cond> 18;	CHANGE <cond> 8.12;	Voltage channel amplitude and phase ON to DELTA.
CHANGE GPIB 74; CHANGE GPIB 76; CHANGE GPIB 78; CHANGE <cond> 8; CHANGE <cond> 18;	CHANGE <cond> 8.15;	Current / voltage channel phase and amplitude ON to DELTA.
CHANGE <cond> 9;	CHANGE <cond> 9.3;	Current channel amplitude and/or phase DELTA to ON.
CHANGE <cond> 19;	CHANGE <cond> 9.10;	Voltage channel amplitude and/or phase DELTA to ON.

5.1.3 Delta Commands - SWING active

This section details the DELTA function commands where the SWING option is used. In other words, if the command is OFF/ON to DELTA, the output will reverse directions for the delta on reaching the final value (S_LEVEL or S_PHASE). This means that the delta function is of an oscillatory nature; the output SWINGS between the initial value (LEVEL or PHASE) and the final value (S_LEVEL or S_PHASE).

CHANGE GPIB 72; CHANGE GPIB 75; CHANGE GPIB 78; CHANGE <cond> 6;	CHANGE <cond> 6.17;	Current channel amplitude OFF to DELTA.

** NOTE ** Version 1.3: If the voltage channel amplitude has a non-zero delta, the voltage channel will begin to delta - even though the output may be off.

CHANGE GPIB 72; CHANGE GPIB 75; CHANGE GPIB 78; CHANGE <cond> 16;	CHANGE <cond> 6.21;	Voltage channel amplitude OFF to DELTA.

** NOTE ** Version 1.3: If the current channel amplitude has a non-zero delta, the voltage channel will begin to delta - even though the output may be off.

CHANGE GPIB 72; CHANGE GPIB 75; CHANGE GPIB 78; CHANGE <cond> 6; CHANGE <cond> 16;	CHANGE <cond> 6.5;	Current and voltage channel amplitude OFF to DELTA.

CHANGE GPIB 73; CHANGE GPIB 76; CHANGE GPIB 78; CHANGE <cond> 6;	CHANGE <cond> 6.2;	Current channel phase OFF to DELTA.
** NOTE ** Version 1.3: If the voltage channel phase has a non-zero delta the voltage phase channel will begin to delta -even though the output may be off.		
CHANGE GPIB 73; CHANGE GPIB 76; CHANGE GPIB 78; CHANGE <cond> 16;	CHANGE <cond> 6.8;	Voltage channel phase OFF to DELTA.
** NOTE ** Version 1.3: If the current channel phase has a non-zero delta, the current channel phase will begin to delta -even though the output may be off.		
CHANGE GPIB 72; CHANGE GPIB 75; CHANGE GPIB 78; CHANGE <cond> 6; CHANGE <cond> 16;	CHANGE <cond> 6.26;	Current and voltage channel phase OFF to DELTA.
CHANGE GPIB 74; CHANGE GPIB 75; CHANGE GPIB 78; CHANGE <cond> 6;	CHANGE <cond> 6.3;	Current channel amplitude and phase OFF to DELTA.
CHANGE GPIB 74; CHANGE GPIB 75; CHANGE GPIB 78; CHANGE <cond> 16;	CHANGE <cond> 6.12;	Voltage channel amplitude and phase OFF to DELTA.
CHANGE GPIB 74; CHANGE GPIB 75; CHANGE GPIB 78; CHANGE <cond> 6; CHANGE <cond> 16;	CHANGE <cond> 6.15;	Current / voltage channel phase and amplitude OFF to DELTA

CHANGE GPIB 76;	CHANGE <cond> 7.16;	DELTA to OFF. This command forces a reset of the SWING bit. Any delta is allowed to continue until the final value is reached.
CHANGE GPIB 72; CHANGE GPIB 75; CHANGE GPIB 78; CHANGE <cond> 8; ** NOTE ** Version 1.3: If the voltage channel amplitude has a non-zero delta, the voltage channel will begin to delta - even though the output may be off.	CHANGE <cond> 8.17;	Current channel amplitude ON to DELTA.
CHANGE GPIB 72; CHANGE GPIB 75; CHANGE GPIB 78; CHANGE <cond> 18; ** NOTE ** Version 1.3: If the current channel amplitude has a non-zero delta, the voltage channel will begin to delta - even though the output may be off.	CHANGE <cond> 8.20;	Voltage channel amplitude ON to DELTA.
CHANGE GPIB 72; CHANGE GPIB 75; CHANGE GPIB 78; CHANGE <cond> 8; CHANGE <cond> 18;	CHANGE <cond> 8.21;	Current and voltage channel amplitude ON to DELTA.
CHANGE GPIB 73; CHANGE GPIB 75; CHANGE GPIB 78; CHANGE <cond> 8; ** NOTE ** Version 1.3: If the voltage channel phase has a non-zero delta the voltage phase channel will begin to delta -even though the output may be off.	CHANGE <cond> 8.18;	Current channel phase ON to DELTA.

CHANGE GPIB 73; CHANGE GPIB 75; CHANGE GPIB 78; CHANGE <cond> 18;	CHANGE <cond> 8.24;	Voltage channel phase ON to DELTA.

** NOTE ** Version 1.3: If the current channel phase has a non-zero delta, the current channel phase will begin to delta -even though the output may be off.

CHANGE GPIB 72; CHANGE GPIB 75; CHANGE GPIB 78; CHANGE <cond> 8; CHANGE <cond> 18;	CHANGE <cond> 8.26;	Current and voltage channel phase ON to DELTA.
CHANGE GPIB 74; CHANGE GPIB 75; CHANGE GPIB 78; CHANGE <cond> 8;	CHANGE <cond> 8.3;	Current channel amplitude and phase ON to DELTA.
CHANGE GPIB 74; CHANGE GPIB 75; CHANGE GPIB 78; CHANGE <cond> 18;	CHANGE <cond> 8.12;	Voltage channel amplitude and phase ON to DELTA.
CHANGE GPIB 74; CHANGE GPIB 76; CHANGE GPIB 78; CHANGE <cond> 8; CHANGE <cond> 18;	CHANGE <cond> 8.15;	Current / voltage channel phase and amplitude ON to DELTA.
CHANGE GPIB 76;	CHANGE <cond> 9.16;	DELTA to ON. This command forces a reset of the SWING bit. Any delta is allowed to continue until the final value is reached.

5.1.4 Delta Commands - ROLL active

The next section details the DELTA function commands where the ROLL option is used. In other words, if the command is OFF/ON to DELTA, the output will restart at the initial value (LEVEL or PHASE) on reaching the final value (S_LEVEL or S_PHASE). This means that the delta function is of an oscillatory nature; the output ROLLS from the initial value (LEVEL or PHASE) to the final value (S_LEVEL or S_PHASE).

CHANGE GPIB 72; CHANGE GPIB 76; CHANGE GPIB 77; CHANGE <cond> 6;	CHANGE <cond> 6.33;	Current channel amplitude OFF to DELTA.

** NOTE ** Version 1.3: If the voltage channel amplitude has a non-zero delta, the voltage channel will begin to delta - even though the output may be off.

CHANGE GPIB 72; CHANGE GPIB 76; CHANGE GPIB 77; CHANGE <cond> 16;	CHANGE <cond> 6.36;	Voltage channel amplitude OFF to DELTA.

** NOTE ** Version 1.3: If the current channel amplitude has a non-zero delta, the voltage channel will begin to delta - even though the output may be off.

CHANGE GPIB 72; CHANGE GPIB 76; CHANGE GPIB 77; CHANGE <cond> 6; CHANGE <cond> 16;	CHANGE <cond> 6.37;	Current and voltage channel amplitude OFF to DELTA.

CHANGE GPIB 73; CHANGE GPIB 76; CHANGE GPIB 77; CHANGE <cond> 6;	CHANGE <cond> 6.34;	Current channel phase OFF to DELTA.

** NOTE ** Version 1.3: If the voltage channel phase has a non-zero delta the voltage phase channel will begin to delta -even though the output may be off.

CHANGE GPIB 73; CHANGE GPIB 76; CHANGE GPIB 77; CHANGE <cond> 16;	CHANGE <cond> 6.40;	Voltage channel phase OFF to DELTA.

** NOTE ** Version 1.3: If the current channel phase has a non-zero delta, the current channel phase will begin to delta -even though the output may be off.

CHANGE GPIB 72; CHANGE GPIB 76; CHANGE GPIB 77; CHANGE <cond> 6; CHANGE <cond> 16;	CHANGE <cond> 6.42;	Current and voltage channel phase OFF to DELTA.
CHANGE GPIB 74; CHANGE GPIB 76; CHANGE GPIB 77; CHANGE <cond> 6;	CHANGE <cond> 6.3;	Current channel amplitude and phase OFF to DELTA.
CHANGE GPIB 74; CHANGE GPIB 76; CHANGE GPIB 77; CHANGE <cond> 16;	CHANGE <cond> 6.12;	Voltage channel amplitude and phase OFF to DELTA.
CHANGE GPIB 74; CHANGE GPIB 76; CHANGE GPIB 78; CHANGE <cond> 6; CHANGE <cond> 16;	CHANGE <cond> 6.15;	Current / voltage channel phase and amplitude OFF to DELTA.

CHANGE GPIB 78;	CHANGE <cond> 7.32;	DELTA to OFF. This command forces a reset of the ROLL bit. Any delta is allowed to continue until the final value is reached.
CHANGE GPIB 72; CHANGE GPIB 76; CHANGE GPIB 77; CHANGE <cond> 8;	CHANGE <cond> 8.33;	Current channel amplitude ON to DELTA.
** NOTE ** Version 1.3: If the voltage channel amplitude has a non-zero delta, the voltage channel will begin to delta - even though the output may be off.		
CHANGE GPIB 72; CHANGE GPIB 76; CHANGE GPIB 77; CHANGE <cond> 18;	CHANGE <cond> 8.36;	Voltage channel amplitude ON to DELTA.
** NOTE ** Version 1.3: If the current channel amplitude has a non-zero delta, the voltage channel will begin to delta - even though the output may be off.		
CHANGE GPIB 72; CHANGE GPIB 76; CHANGE GPIB 77; CHANGE <cond> 8; CHANGE <cond> 18;	CHANGE <cond> 8.41;	Current and voltage channel amplitude ON to DELTA.
CHANGE GPIB 73; CHANGE GPIB 76; CHANGE GPIB 77; CHANGE <cond> 8;	CHANGE <cond> 8.34;	Current channel phase ON to DELTA.
** NOTE ** Version 1.3: If the voltage channel phase has a non-zero delta the voltage phase channel will begin to delta -even though the output may be off.		

CHANGE GPIB 73; CHANGE GPIB 76; CHANGE GPIB 77; CHANGE <cond> 18;	CHANGE <cond> 8.40;	Voltage channel phase ON to DELTA.
** NOTE ** Version 1.3: If the current channel phase has a non-zero delta, the current channel phase will begin to delta -even though the output may be off.		
CHANGE GPIB 72; CHANGE GPIB 76; CHANGE GPIB 77; CHANGE <cond> 8; CHANGE <cond> 18;	CHANGE <cond> 8.37;	Current and voltage channel phase ON to DELTA.
CHANGE GPIB 74; CHANGE GPIB 76; CHANGE GPIB 77; CHANGE <cond> 8;	CHANGE <cond> 8.3;	Current channel amplitude and phase ON to DELTA.
CHANGE GPIB 74; CHANGE GPIB 76; CHANGE GPIB 78; CHANGE <cond> 18;	CHANGE <cond> 8.12;	Voltage channel amplitude and phase ON to DELTA.
CHANGE GPIB 74; CHANGE GPIB 76; CHANGE GPIB 78; CHANGE <cond> 8; CHANGE <cond> 18;	CHANGE <cond> 8.15;	Current / voltage channel phase and amplitude ON to DELTA.
CHANGE GPIB 76;	CHANGE <cond> 9.16;	DELTA to ON. This command forces a reset of the SWING bit. Any delta is allowed to continue until the final value is reached.

5.1.5 Delta Commands - SWING and ROLL active

The last section details the DELTA function commands where the SWING and ROLL option is used. In other words, if the command is OFF/ON to DELTA, the phase angles will restart at the initial phase (PHASE) on reaching the final phase value (S_PHASE). For the amplitudes, the delta function will reverse direction on reaching the final value (S_LEVEL) and also reverse directions on reaching the initial value (LEVEL). Note that the ROLL option overrides the SWING option for the current and voltage phase only. **Amplitudes are NOT affected by the ROLL bit when both SWING and ROLL are active. The ROLL bit will always override the SWING bit for phase ramping.**

CHANGE GPIB 72; CHANGE GPIB 75; CHANGE GPIB 77; CHANGE <cond> 6;	CHANGE <cond> 6.49;	Current channel amplitude OFF to DELTA. Current amplitude will SWING.

** NOTE ** Version 1.3: If the voltage channel amplitude has a non-zero delta, the voltage channel will begin to delta - even though the output may be off.

CHANGE GPIB 72; CHANGE GPIB 75; CHANGE GPIB 77; CHANGE <cond> 16;	CHANGE <cond> 6.52;	Voltage channel amplitude OFF to DELTA. Voltage amplitude will SWING.

** NOTE ** Version 1.3: If the current channel amplitude has a non-zero delta, the voltage channel will begin to delta - even though the output may be off.

CHANGE GPIB 72; CHANGE GPIB 75; CHANGE GPIB 77; CHANGE <cond> 6; CHANGE <cond> 16;	CHANGE <cond> 6.53;	Current and voltage channel amplitude OFF to DELTA. Both amplitudes will SWING.

CHANGE GPIB 73; CHANGE GPIB 75; CHANGE GPIB 77; CHANGE <cond> 6;	CHANGE <cond> 6.50;	Current channel phase OFF to DELTA. Current channel phase will ROLL.

** NOTE ** Version 1.3: If the voltage channel phase has a non-zero delta the voltage phase channel will begin to delta -even though the output may be off.

CHANGE GPIB 73; CHANGE GPIB 75; CHANGE GPIB 77; CHANGE <cond> 16;	CHANGE <cond> 6.56;	Voltage channel phase OFF to DELTA. Voltage channel phase will ROLL.

** NOTE ** Version 1.3: If the current channel phase has a non-zero delta, the current channel phase will begin to delta -even though the output may be off.

CHANGE GPIB 72; CHANGE GPIB 75; CHANGE GPIB 77; CHANGE <cond> 6; CHANGE <cond> 16;	CHANGE <cond> 6.58;	Current and voltage channel phase OFF to DELTA. Both voltage and current phase will ROLL.
CHANGE GPIB 74; CHANGE GPIB 75; CHANGE GPIB 77; CHANGE <cond> 6;	CHANGE <cond> 6.51;	Current channel OFF to DELTA. The amplitude will SWING and the phase will ROLL.
CHANGE GPIB 74; CHANGE GPIB 75; CHANGE GPIB 77; CHANGE <cond> 16;	CHANGE <cond> 6.60;	Voltage channel OFF to DELTA. The amplitude will SWING and the phase will ROLL.
CHANGE GPIB 74; CHANGE GPIB 75; CHANGE GPIB 77; CHANGE <cond> 6; CHANGE <cond> 16;	CHANGE <cond> 6.63;	Current and voltage channel amplitude and phase OFF to DELTA. Both voltage and current phase channels will ROLL and the amplitudes will SWING.

CHANGE GPIB 76; CHANGE GPIB 78;	CHANGE <cond> 7.48;	DELTA to OFF. This command forces a reset of the ROLL and SWING bits. Any delta is allowed to continue until the final value is reached.
CHANGE GPIB 72; CHANGE GPIB 75; CHANGE GPIB 77; CHANGE <cond> 8; ** NOTE ** Version 1.3: If the voltage channel amplitude has a non-zero delta, the voltage channel will begin to delta - even though the output may be off.	CHANGE <cond> 8.49;	Current channel amplitude ON to DELTA. Current channel amplitude will SWING.
CHANGE GPIB 72; CHANGE GPIB 75; CHANGE GPIB 77; CHANGE <cond> 18; ** NOTE ** Version 1.3: If the current channel amplitude has a non-zero delta, the voltage channel will begin to delta - even though the output may be off.	CHANGE <cond> 8.52;	Voltage channel amplitude ON to DELTA. Voltage channel will SWING.
CHANGE GPIB 72; CHANGE GPIB 75; CHANGE GPIB 77; CHANGE <cond> 8; CHANGE <cond> 18;	CHANGE <cond> 8.53;	Current and voltage channel amplitude ON to DELTA. Both amplitudes will SWING.

CHANGE GPIB 73; CHANGE GPIB 75; CHANGE GPIB 77; CHANGE <cond> 8;	CHANGE <cond> 8.50;	Current phase ON to DELTA. The current channel phase will ROLL.

** NOTE ** Version 1.3: If the voltage channel phase has a non-zero delta the voltage phase channel will begin to delta -even though the output may be off.

CHANGE GPIB 73; CHANGE GPIB 75; CHANGE GPIB 77; CHANGE <cond> 18;	CHANGE <cond> 8.56;	Voltage channel phase ON to DELTA. The voltage channel phase will ROLL.

** NOTE ** Version 1.3: If the current channel phase has a non-zero delta, the current channel phase will begin to delta -even though the output may be off.

CHANGE GPIB 72; CHANGE GPIB 75; CHANGE GPIB 77; CHANGE <cond> 8; CHANGE <cond> 18;	CHANGE <cond> 8.58;	Current and voltage channel phase ON to DELTA. Both phase channels will ROLL.
CHANGE GPIB 74; CHANGE GPIB 75; CHANGE GPIB 77; CHANGE <cond> 8;	CHANGE <cond> 8.51;	Current channel ON to DELTA. The amplitude will SWING and the phase will ROLL.
CHANGE GPIB 74; CHANGE GPIB 75; CHANGE GPIB 77; CHANGE <cond> 18;	CHANGE <cond> 8.60;	Voltage channel ON to DELTA. The amplitude will SWING and the phase will ROLL.
CHANGE GPIB 74; CHANGE GPIB 75; CHANGE GPIB 77; CHANGE <cond> 8; CHANGE <cond> 18;	CHANGE <cond> 8.63;	Current and voltage channel amplitude and phase ON to DELTA. Both voltage and current phase channels will ROLL and the amplitudes will SWING.

CHANGE GPIB 76; CHANGE GPIB 78;	CHANGE <cond> 9.48;	DELTA to ON. This command forces a reset of the SWING and ROLL bits. Any delta is allowed to continue until the final value is reached.

6.0 Voltage and Current Levels per Range

The table below lists the allowable range for each tap on the current and voltage channels.

Tap ID	Nominal Tap Value	Tap Change Lower Limit	Tap Change Upper Limit	Maximum Limit	Mode
Tap1	3.125 A	----	3.125 A	4.000 A	EPOCH-I/10
Tap2	12.50 A	3.125 A	12.50 A	20.00 A	EPOCH-I/10
Tap3	25.00 A	12.50 A	----	31.00 A	EPOCH-I/10
Tap1	40.00 V	----	40.00 V	40.00 V	EPOCH-I/10
Tap2	150.0 V	40.0 V	150.00 V	155.0 V	EPOCH-I/10
Tap3	300.0 V	150.0 V	----	310.0 V	EPOCH-I/10
Tap1	10.00 A	----	----	11.00 A	EPOCH-II/20
Tap2	15.00 A	----	----	16.50 A	EPOCH-II/20
Tap3	40.00 A	----	----	44.00 A	EPOCH-II/20
Tap4	50.00 A	----	----	55.00 A	EPOCH-II/20
Tap5	100.0 A	----	----	110.0 A	EPOCH-II/20
Tap6	170.0 A	----	----	187.0 A	EPOCH-II/20

Table 5: Voltage and Current Levels per Range

EASI FILE CORP. IRVINE, CA EFH 22

19043D 1 OF 2 4

DWG. NO. 19043D		
REV.	ECN	DATE
1	18151	8-14-85
2	18594	11-22-85
3	20000	10 28 86
4	25475	8/23/93

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TOLERANCES: DECIMAL ±.010 FRACTIONAL ±1/64 UNLESS NOTED | DWN. WJF | APPD. PRR | SCALE ~
CHK'D. | DATE 2-27-84 | SHT. 1 OF 2

TITLE EPOCH-I FRONT PANEL I/O BOARD

PART NO. 8380 | DWG. NO. 19043D | REV. 4

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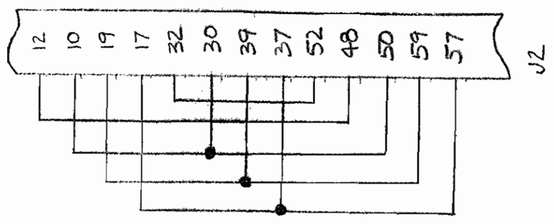

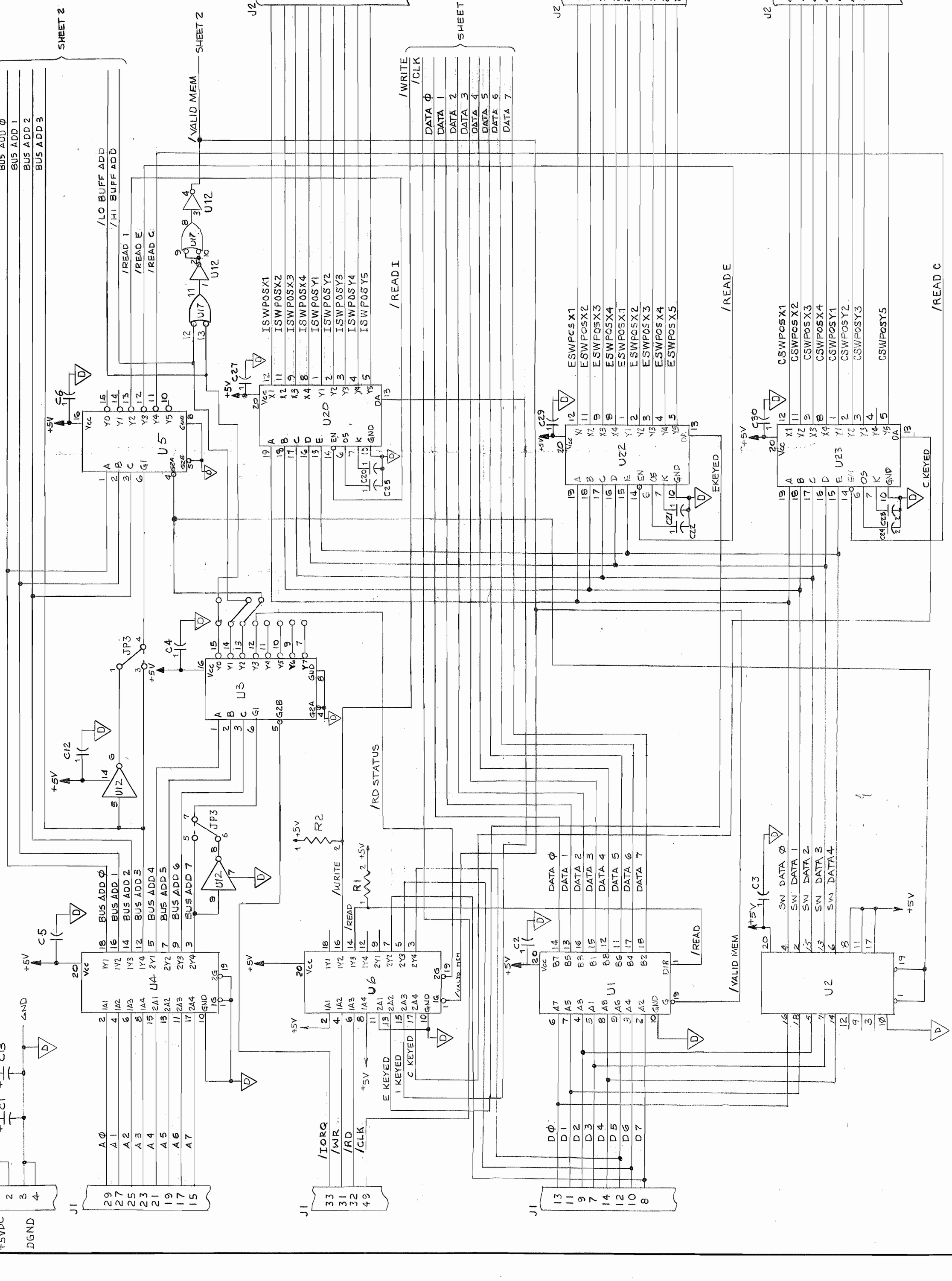

19043D

EASI FILE CORP. IRVINE, CA EFH 22

2 OF 2

3 4

DWG. NO. 19043D

REV.	ECN	DATE

J2 connector pinout: 13 /SERDATA, 14 /SHIFTCLK, 11 +5VDC, 12, 20 DGND, 19, 15 CNT64, 16 CNT32, 18 CNT128, 33 ESERDATA, 34 /SHIFTCLK, 31 +5VDC, 32, 40 DGND, 39, 35 CNT64, 36 CNT32, 38 CNT128, 53 ESERDATA, 54 /SHIFTCLK, 51 +5VDC, 52, 60 DGND, 59, 55 CNT64, 56 CNT32, 58 CNT128

LATCH E

LATCH I

U21, U15, U16: 74LS299 universal shift/storage register

DATA Φ, DATA 1, DATA 2, DATA 3, DATA 4, DATA 5, DATA 6, DATA 7

/SHIFTCLOCK

U12: 74LS14 hex Schmitt inverter; R3 1K; C32 1

U14: 74LS139 dual 2-to-4 decoder; COUNT2, COUNT4, COUNT8, COUNT16

U13: 74LS157 quad 2-to-1 multiplexer; 4 /LO BUFF, 7 /HI BUFF

U17: 74LS08 quad 2-input AND; 3 /SHIFT CLOCK

R5 1K; C33 1

COUNT 64, COUNT 32, COUNT 128

U18: 74LS157; BUS ADD Φ, BUS ADD 1, BUS ADD 2, BUS ADD 3, /VALID MEM

U19, U24: 74LS161 4-bit binary counter; COUNT 1, COUNT 2, COUNT 4, COUNT 8, COUNT 16, COUNT 32, COUNT 64, COUNT 128

U9, U10: 74LS244 octal buffer; HI BUFF

U8, U11: 74LS244 octal buffer; /LO BUFF

MEM ADD 3, MEM ADD 2, MEM ADD 1, MEM ADD Φ

U7: 74LS244 octal buffer; 1G, 2G

/DATA Φ, /DATA 1, /DATA 2, /DATA 3, /DATA 4, /DATA 5, /DATA 6, /DATA 7

/VALIDMEM, /WRITE

C15, C18, C14, C26, C31, C19, C9, C16, C17, C10, C8, C11, C7: 1 µF

R4 1K

+5V

SHEET 1 /VALID MEM, /LO BUFF ADD, /HI BUFF ADD

SHEET 1 /CLK

SHEET 1 BUS ADD Φ, BUS ADD 1, BUS ADD 2, BUS ADD 3, /VALIDMEM

SHEET 1 DATA Φ, DATA 1, DATA 2, DATA 3, DATA 4, DATA 5, DATA 6, DATA 7

SHEET 1 /VALIDMEM, /WRITE

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TOLERANCES: DECIMAL ±.010, FRACTIONAL ±1/64, UNLESS NOTED

DWN. WJF | APPD. PRR | SCALE ~

CHK'D. | DATE 2-27-84 | SHT. 2 OF 2

TITLE EPOCH-1 FRONT PANEL I/O BOARD

PART NO. 8380 | DWG. NO. 19043D | REV. 4

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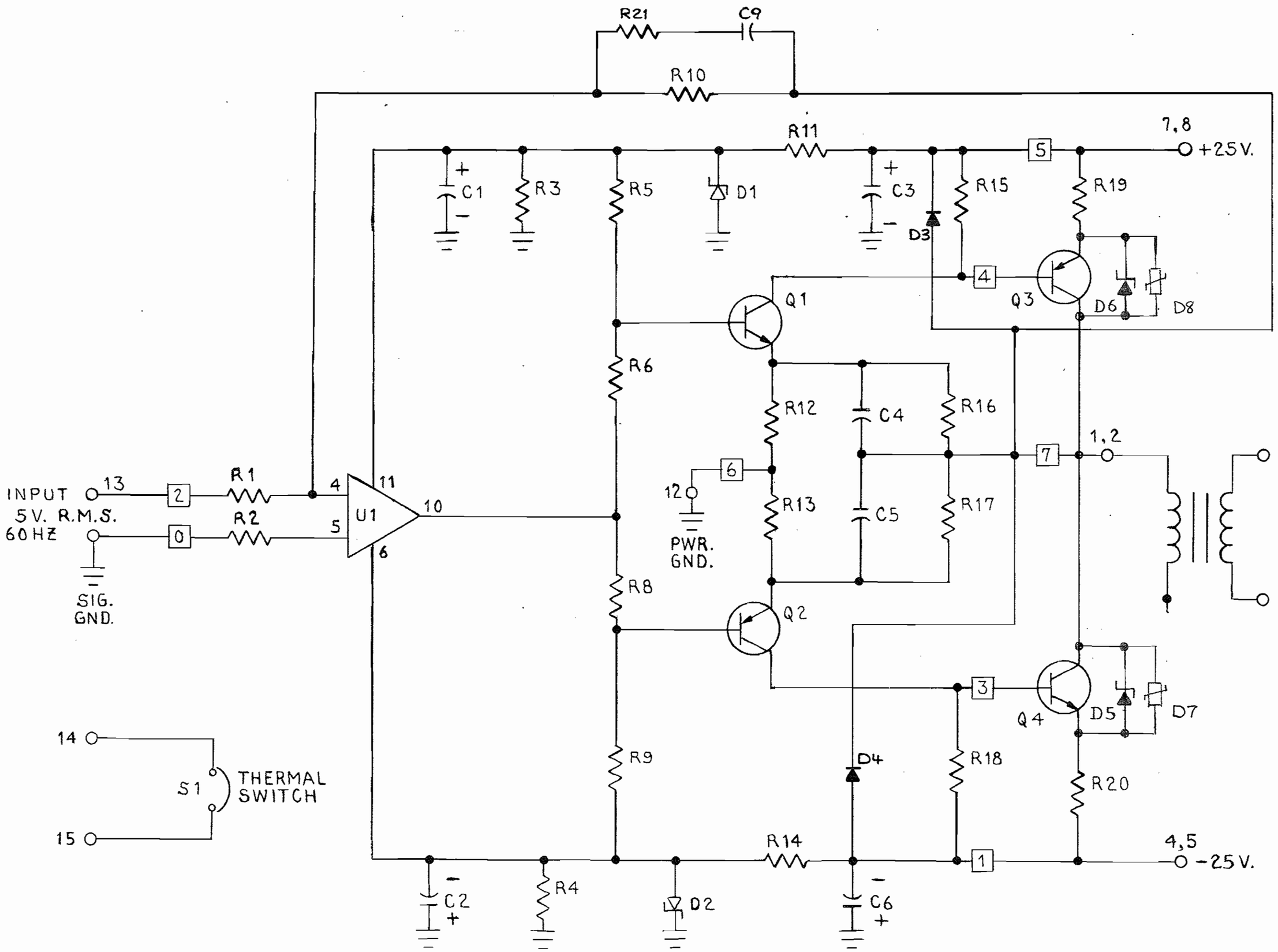
DWG. NO.	19620C		
REV.	E.C.N.	DATE	REMARKS
1	17430	7-16-85	
2	19397	6-2-86	
3	23644	6-1-91	
4	25328	11/3/93	
5	25769	3MAR94	



ITEM	PART NO.	DESCRIPTION	QTY.
U1	4730	OP-AMP 741A	1
S1	4646	THERMAL SWITCH	1
R21	3436	RESISTOR 150Ω RN60D 1%	1
R19,20	4638	RESISTOR 0.1Ω 10W	2
R16,17	3434	RESISTOR 100Ω 1%	2
R15,18	3446	RESISTOR 402Ω 1%	2
R12,13	1487	RESISTOR 30Ω 1% 5W	2
R11,14	7502A	RESISTOR 218Ω 2¼W	2
R10	4627	RESISTOR 44.2K 1%	1
R6,8	3436	RESISTOR 150Ω 1%	2
R5,9	3484	RESISTOR 4.02K	2
R3,4	3475	RESISTOR 1.5K	2
R1,2	3486	RESISTOR 4.99K	2
Q4	11967	TRANSISTOR MJ14002	1
Q3	11968	TRANSISTOR MJ14003	1
Q2	15609	TRANSISTOR 2N6191	1
Q1	15608	TRANSISTOR 2N5337	1
D7,D8	13966	TRANZORB	2
D5,D6	13794	DIODE MVR410	2
D3,4	3063	DIODE IN4004	2
D1,2	1849	ZENER DIODE IN4744A	2
C9	6510	CAPACITOR .047 µf	1
C7	---	NOT USED	--
C4,5	4274	CAPACITOR 0.1 µf	2
C3,6	1413	CAPACITOR 100 µf	2
C1,2	7986	CAPACITOR 22µf	2

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TOLERANCES: DECIMAL ±.010 FRACTIONAL ±1/64 UNLESS NOTED	DWN. RMD	APPD. PRR	SCALE: N
	CHKD.	DATE 7-1-85	SH. 1 OF 1

TITLE SCHEMATIC, VOLT AMPLIFIER, EPOCH

PART NO	DWG NO.	REV.
9634	19620C	5

20962D

EASI FILE CORP. IRVINE, CA EFH 22

1 OF 3

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DWG. NO. 20962D			
REV.	E.C.N.	DATE	REMARKS
1	16097	9-25-84	
2	16428	11-20-84	ADDED R 8-12, (B/A)
3	16479	1-25-85	
4	17782	8-8-85	
5	18768	2-3-86	
6	19764	9-4-86	
7	20000	10 29 86	
8	20442	3 24 87	
9	20602	5 21 87	
10	24413	5-6-92	

REF. DES.	PART NO.	DESCRIPTION	QTY
U23	9199	P.C. BOARD	1
	9197-1.00	ASS'Y, EPOCH 1 I.C. PROG 0013	1
VR2	11107	I.C., REG. LM79M15CP 15V. NEG.	1
VR1	11108	I.C., REG. LM78M15CP 15V. POS.	1
U23 (REF)	8207	I.C., EPROM 2532 4K x 8	1
U20	8699	74LS20	1
U19	8029	74LS04	1
U17	8693	DAC-08H	1
U12, 14, 16, 21, 22	8695	74LS283	5
U11, 13, 15	9048	74LS161A	3
U9, 18	8031	74LS244	2
U8, 26	6343	OP-07EP OP-AMP	2
U7	9858	7541 AKN	1
U4-6, 24	8401	74LS374	4
U3	9202	74LS375	1
U2	8034	74LS245	1
U1, 10	6979	I.C., 74LS138	2
R12	8569	POT 500Ω SIDE ADJ.	1
R4, 7	9860	RESISTOR 2.55 KΩ 0.1% RN55J	2
R3, 6	9859	RESISTOR 2KΩ 0.1% RN55J	2
Q1	4649	TRANSISTOR, AD581J 10V.	1
C30, 31	7986	CAPACITOR 22 μF 35V.	2
C33	6525	100 PF	1
C10, 11, 28, 29	6502	2.2 μF 25V.	4
C34, 17	8886	430 PF	2
C23	8989	1000 PF 100V. DC	1
C36, 13, 14, 16, 18-22, 24-27	6270	0.1 μF	18
C35, C32			
C1	9201	CAPACITOR 68 μF 6V.	1

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TOLERANCES: DECIMAL ±.010 FRACTIONAL ±1/64 UNLESS NOTED | DWN. ADF | APPD. PRR | SCALE: NONE | DATE 3-8-84 | SH. 1 OF 3

TITLE SCHEMATIC — UNIVERSAL SINE GENERATOR

PART NO. 9200 | DWG. NO. 20962D | REV. 10

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C2 NOT USED

SPARES

NOTE: NON-STANDARD FIVE VOLT AND GROUND PINS ON THE 74LS375 DEVICE.

20962D 2 OF 3 18

EASI FILE CORP. IRVINE, CA EFH 22

DWG. NO. 20962 D			
REV.	E.C.N.	DATE	REMARKS

NOTES

1. FOR 2532 EPROM REFER TO SCH. REV 9

SHEET 3

DAC DATA Ø — U17-12
DAC DATA 1 — U17-11
DAC DATA 2 — U17-10
DAC DATA 3 — U17-9
DAC DATA 4 — U17-8
DAC DATA 5 — U17-7
DAC DATA 6 — U17-6
DAC DATA 7 — U17-5

U24 LS374 — C27 — +5V.

U23 2732 — C26 — +5V.

PROM ADD Ø
PROM ADD 1
PROM ADD 2
PROM ADD 3
PROM ADD 4
PROM ADD 5
PROM ADD 6
PROM ADD 7
PROM ADD 8
PROM ADD 9
PROM ADD 10
PROM ADD 11

U22 LS283 — C25 — +5V.
U21 LS283 — +5V.

U16 LS283 — C20 — +5V.
U14 LS283 — +5V.
U12 LS283 — +5V.

OFFSET Ø
OFFSET 1
OFFSET 2
OFFSET 3
OFFSET 4
OFFSET 5
OFFSET 6
OFFSET 7
OFFSET 8
OFFSET 9
OFFSET 10
OFFSET 11

PHASE CNT. Ø
PHASE CNT. 1
PHASE CNT. 2
PHASE CNT. 3
PHASE CNT. 4
PHASE CNT. 5
PHASE CNT. 6
PHASE CNT. 7
PHASE CNT. 8
PHASE CNT. 9
PHASE CNT. 10
PHASE CNT. 11

1/2 LS20 — U20 — +5V.

U15 LS161A — C24 — +5V.
U13 LS161A — +5V.
U11 LS161A — C19 — +5V.

3599

U4-12
U4-9
U4-15
U4-6
SHEET 1

J1 45 /VAROUT — +5V.

U4-16
U4-5
U4-19
U4-2
SHEET 1

J1 49 /VARCLK — +5V.

U3-5
U3-3
U3-11
U3-13
SHEET 1

+5V.

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TOLERANCES: DECIMAL ±.010 FRACTIONAL ±1/64 UNLESS NOTED
DWN. ADF | APPD. PRR | SCALE: ~
CHKD. | DATE 3-8-84 | SH. 2 OF 3

TITLE SCHEMATIC—UNIVERSAL SINE GENERATOR
PART NO. 9200 | DWG. NO. 20962 D | REV. 10

REV.	E.C.N.	DATE	REMARKS

NOTE 1
DIGITAL GROUND AND ANALOG GROUND TIE TOGETHER AT PINS 3 AND 4 AND NOWHERE ELSE.

J1
+5VDC 1
2
DGND 3
4
+24VDC 55
-24VDC 56

+5V.
C1 68/6
NOTE 1
+15V.
VR1 LM78M15CP (LM342)
IN OUT
C31 10/20
C29 2.2/25
-15V.
VR2 LM79M15CP (LM320)
C30 10/20
C28 2.2/20

+5V BYPASS CAPS IN ADDITION TO THE 0.1's DIRECTLY CONNECTED TO THE 74LS245 AND THE 2532 AS SHOWN. 2 OR 3 SHOULD BE EVENLY SPACED ALONG POWER AND GROUND BUS TO OTHER IC'S.

VR1 (LM78M15) IN GND. OUT
VR2 (LM79M15) GND IN OUT

SHEET 1
DATA 7
DATA 6
DATA 5
DATA 4
DATA 3
DATA 2
DATA 1
DATA Ø

+5V C5
U5 LS374
3 18 4 17 7 14 8 13
2 19 5 16 6 15 9 12
U10-13 11 LD HI GAIN SHEET 1
1 10

+5V C6
U6 LS374
3 18 4 17 7 14 8 13
2 19 5 16 6 15 9 12
U10-12 11 LD LO GAIN SHEET 1
1 10

J1
/OUTPUTEN 28
SYNC 26
/OUTPUTDIS 24
(SPARE OUTPUT) 22

U7 AD7541AKN
D11 4
D10 5
D9 6
D8 7
D7 8
D6 9
D5 10
D4 11
D3 12
D2 13
D1 14
DØ 15
Vcc
D GND. 3
V+ 16
R FB. 18
I₀ 1
A GND. 2
VR REF. 17

+15V C7 .1
500Ω METAL FILM TRIM POT 20 TURN
C.W
C33 100 PF MICA
+15V. C32 .1
U26 OP07
C35 .1
-15V.
TP2
+15V C14 0.1
C11 2.2/25
VOUT AD581J GND
C10 2.2/25
+15V VOUT GND
TOP VIEW
AD581

SHEET 2
DAC DATA Ø 5
DAC DATA 1 6
DAC DATA 2 7
DAC DATA 3 8
DAC DATA 4 9
DAC DATA 5 10
DAC DATA 6 11
DAC DATA 7 12

U17 DACØ8H
D7 D6 D5 D4 D3 D2 D1 DØ
Vcc 16
C_c
V+ 13
I_o 2
I_o 4
V- 3
VR+ 14
VR- 15

C22 0.1
C23 MICA 1000 PF
R7 2.55K 0.1% RN55J
R4 2.55K 0.1% RN55J
C21 0.1% -15V
TP1

C17 430PF MICA
R3 2.0K .1% RN55J
+15V C13 0.1
U8 OPØ7
C34 430 PF MICA
R6 2.0K 0.1% RN55J
C16 0.1
-15V

J1
6 ESINE

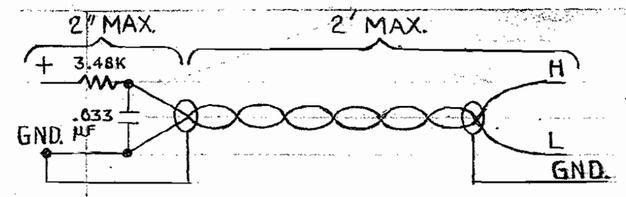
NOTE 4

NOTE
① THE 2.2 μF CAPS ON THESE FOUR CHIPS MAY BE REDUCED TO AS FEW AS ONE EACH ON -15 AND +15 IF THE CHIPS ARE VERY CLOSE. THE 0.1 μF SHOULD BE DISTRIBUTED AS SHOWN.

② ANALOG GROUND MUST BE A GROUND PLANE BELOW DACS & OP AMPS.

③ CALIBRATION:
SET E.CH. FRONT PANEL TO 40.0 V.
USE FLUKE 8506A
(MODE ENHANCED ACCURACY WITH EXTERNAL GUARD (EXT. GD. IN)
DO NOT USE AN EXTENDER CARD.
ALLOW 10 MINUTE BOARD WARM-UP.
ALLOW 30 MINUTE FLUKE WARM-UP.

MEASURE TEST POINT THROUGH TEST PROBE SHOWN BELOW FOR 5.5205 ± .001



④ ADD TEST POINT TO THIS LINE AND ANALOG GROUND NEAR USER END OF BOARD.

⑤ POSITION OP-AMPS DACS, VOLTAGE SOURCE & POT AS CLOSE TOGETHER AS POSSIBLE.

⑥ CALIBRATION PROCEDURE USED ONLY IN SPECIAL CASE WHEN AUTOMATIC TEST/CALIBRATION NOT PERFORMED.

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TOLERANCES: DECIMAL ± .010 FRACTIONAL ± 1/64 UNLESS NOTED	DWN. RMD	APPD. PRR	SCALE: 2
	CHKD.	DATE 3-8-94	SH. 3 OF 3

TITLE: SCHEMATIC-UNIV. SINE GEN.

PART NO.	DWG. NO.	REV.
9200	20962D	103

20962D 3 OF 3 103

20971D

EASI FILE CORR. IRVINE, CA EFH 22

1 OF 2

11

	DWG. NO.	20971D	
	REV.	E.C.N.	DATE
9	21115	10 29 87	
10	23392	2 6 91	
11	24582	7-27-92	

REV.	E.C.N.	DATE	REMARKS
1	15433	6.5.84	
2	Removed		
3	15443	7.6.84	
4	16100	9-27-84	
5	16582	2-7-85	
6	18553	11-8-85	
7	20627	5 29 87	
8	20886	8 17 87	

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TOLERANCES: DECIMAL ±.010 FRACTIONAL ±1/64 UNLESS NOTED
DWN. RMD | APPD. PRR | SCALE: NONE
CHKD. | DATE 2-29-84 | SH. 1 OF 2

TITLE SCH, TIMING GENERATOR, EPIO
PART NO. 9211 | DWG. NO. 20971D | REV. 11

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20971D

EASI FILE CORP. IRVINE, CA EFH 22

2 OF 2

DWG. NO. 20971D			
REV.	E.C.N.	DATE	REMARKS

REF. DES.	PART NO.	DESCRIPTION	QTY.
C1	9201	CAPACITOR, 86 µF 6V.	1
C3,4	7986	22µF 35V.	2
C5-12,14, 17-25	6270	0.1µF 50V.	18
C15	6975	1µF	1
C16	8162	CAPACITOR, 30pF MICA 5%	1
R1,11	3480	2K Ω 1/4W. 1%	2
R2	8925	RESISTOR 8.06K 1/8W 1%	1
R3	3975	100K	1
R4	4624	200K	1
R5,10	3486	4.99K Ω 1/4W. 1%	2
R6	3490	6.98K	1
R7	3495	10K Ω 1/4W. 1%	1
R8		REMOVED	
R9	3500	RESISTOR, 14K Ω 1/4W. 1%	1
U1	8034	I.C., 74LS245	1
U2,3,6,7,9	8031	74LS244	5
U4,5	6979	74LS138	2
U8	8401	74LS374	1
U10	3806	LM 311	1
17,20			
U11,12,14	8743	MC3448	5
U13	8697	74LS157	1
U15	8029	74LS04	1
U16	8161	4046 CMOS. MOTOROLA ONLY	1
U18,19	8694	74LS153	2
U21	8977	74LS00	1
U22	8433	74LS74	1
U23-28	8698	74LS163	6
U29	8074	MC78L15 REG.+15V.	1
U30	8073	I.C., MC79L15 REG.-15V.	1
Z1-3	6612	RES. NETWORK, SIP 4.7K Ω x7	3

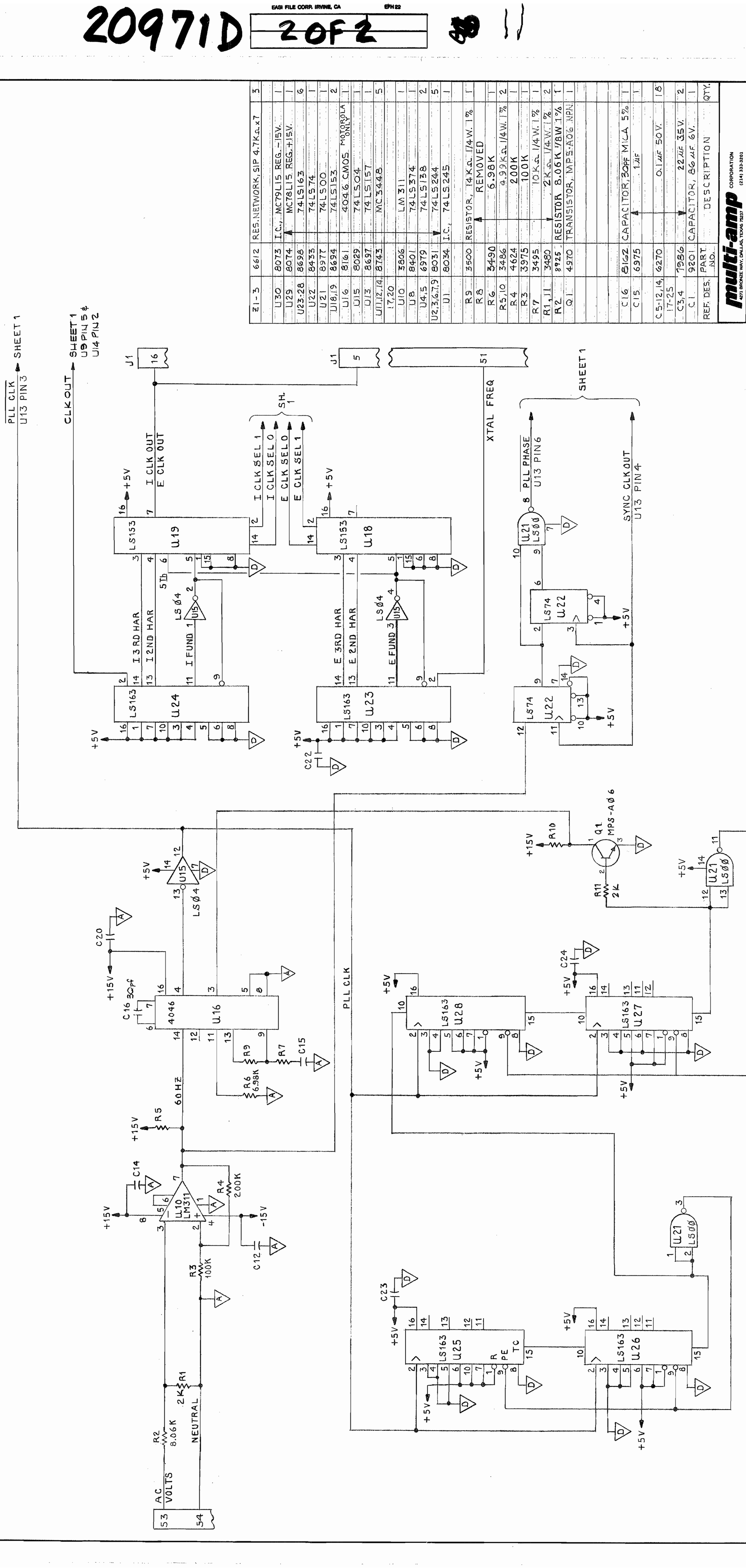
multi-amp CORPORATION
4271 BRONZE WAY, DALLAS, TEXAS 75237 (214) 333-3201

TOLERANCES: DECIMAL ±.010 FRACTIONAL ±1/64 UNLESS NOTED	DWN. RMD	APPD. PRR	SCALE: NJ
	CHKD.	DATE 2-29-84	SH. 2 OF 2

TITLE SCH, TIMING GENERATOR, EPIO

PART NO. 9211 DWG. NO. 20971D REV. 11

THE DEVICE DEPICTED AND DESCRIBED HEREON EMBODIES PROPRIETARY DESIGN OWNED BY MULTI-AMP CORP. ALL DESIGN, MANUFACTURING, REPRODUCTION, SALES AND PATENT RIGHTS REGARDING THIS DEVICE OR DRAWING ARE RESERVED. EXCEPT WHERE EXPLICIT RIGHT IS GRANTED IN WRITING.



21001 D

EASI FILE CORP. IRVINE, CA EFH 22

1 OF 2

4

DWG. NO. 21001 D

REV.	ECN	DATE
1	15025	3-12-84
2	15520	6-27-84
3	17132	4-15-85
4	23392	2 6 91

* DELETE R1, C7, C2, C8

REF. DES.	PART NO.	DESCRIPTION	QTY.
C15	8739	CAPACITOR 5.5-50pF	1
C9	8738	CAPACITOR 56pF	1
C12	7987	CAPACITOR 220pF	1
C3-6,8-11,13,14	6270	CAPACITOR .01 50V	9
C1	9201	CAPACITOR 68µF/6V	1
Y1	8731	CRYSTAL 6.48 MHZ	1
R2-4	3471	RESISTOR 1.1K	3
R1	6556	RESISTOR 90.9Ω	1
U14	7974	I.C. 7400 QUAD 2 INPUT	1
U11,12,15-17	8698	I.C. 74LS163 4BIT COUNTER	5
U10	9247	I.C. 74LS32 QUAD 2 INPUT NAND	1
U8	8029	I.C. 74LS04 HEX INVERTER	1
U7,9	6979	I.C. 74LS138 1OF8 DEMUX	2
U6,13	8433	I.C. 74LS74 DUAL D/F-F	2
U3,4,5	8031	I.C. 74LS 244 OCTAL 3 STATE	3
U2	8401	I.C. 74LS 374 OCTAL D/F-F	1
U1	8034	I.C. 74LS245 OCTAL BUS INA	1

multi-amp CORPORATION
4271 BRONZE WAY, DALLAS, TEXAS 75237 (214) 333-3201

TOLERANCES: DECIMAL ±.010 FRACTIONAL ±1/64 UNLESS NOTED
DWN. | APPD. PRR | SCALE ~
CHK'D. | DATE 11-3-83 | SHT. 1 OF 2

TITLE SCHEMATIC-INTERFACE/OSC

PART NO. 9230 | DWG. NO. 21001 D | REV. 4

THE DEVICE DEPICTED AND DESCRIBED HEREON EMBODIES PROPRIETARY DESIGN OWNED BY MULTI-AMP CORP. ALL DESIGN, MANUFACTURING, REPRODUCTION, SALES AND PATENT RIGHTS REGARDING THIS DEVICE OR DRAWING ARE RESERVED, EXCEPT WHERE EXPLICIT RIGHT IS GRANTED IN WRITING.

+5 V.
WRITE
BUS ADD Ø
BUS ADD 1
BUS ADD 2
BUS ADD 3
BUS ADD 4
BUS ADD 5
BUS ADD 6
BUS ADD 7
RD INT
RD DATA
LD DATA
PHASE OUT
PHASE INT.
SYS. RESET
VALID ADD
I.O REQUEST
INTRQ*
DATA Ø
DATA 1
DATA 2
DATA 3
DATA 4
DATA 5
DATA 6
DATA 7
E RANGE
ALARM
X2 E RANGE
I RANGE 1
I RANGE 2
I RANGE 3
TIMER START
50/60 HZ SELECT SH. 2
WR*
RD*
VOLTS APP'D
CONTINUITY
I.O. RQ.*
SYS. RESET*
PHASE OUT*
READ
VALID ADD
U1
U2
U3
U4
U5
U7
U9
U13
C2
C3
C4
C5
C6
C8
J1
J1
LS74
U16
5V
+5V
N/C

21001 D

EASI FILE CORP. IRVINE, CA EFH22

2 OF 2

4

DWG. NO. 21001 D		
REV.	E.C.N.	DATE	REMARKS

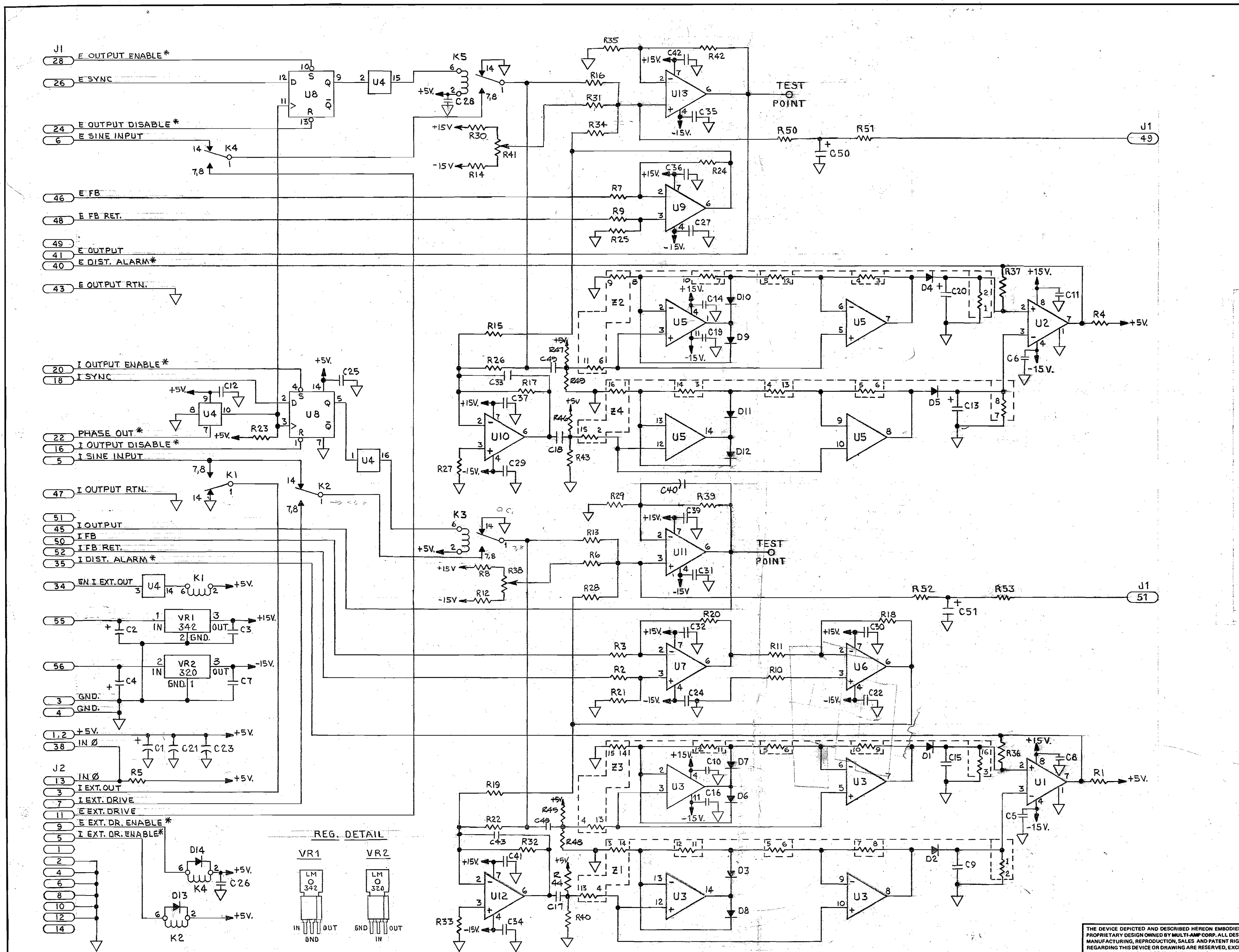
multi-amp CORPORATION
4271 BRONZE WAY, DALLAS, TEXAS 75237 (214) 333-3201

TOLERANCES: DECIMAL ±.010 FRACTIONAL ±1/64 UNLESS NOTED
DWN.
CHKD.
APPD. PRR
DATE 11-3-83
SCALE:
SH. 2 OF 2

TITLE SCHEMATIC INTERFACE/OSC
PART NO. 9230
DWG. NO. 21001 D
REV. 4

THE DEVICE DEPICTED AND DESCRIBED HEREON EMBODIES PROPRIETARY DESIGN OWNED BY MULTI-AMP CORP. ALL DESIGN, MANUFACTURING, REPRODUCTION, SALES AND PATENT RIGHTS REGARDING THIS DEVICE OR DRAWING ARE RESERVED, EXCEPT WHERE EXPLICIT RIGHT IS GRANTED IN WRITING.

J1 16 — K1 — D1 — Q1 — U3-19 — R8
J1 20
J1 5
R5 R6 R7
U15 LS163 — U16 LS163 — U17 LS163 — U12 LS163 — U11 LS163
C10 C11 C9 C8 C7
U10 LS132 — U14 7400
J1 49 COUNTER RESET
TP1
+5V. R1
U1 XTAL PHASE * — XTAL CLOCK — XTAL FREQ.
XTL CLK
60/50HZ SH 1
Y1, 6.48 MHZ — C12 220PF — C13 5.5-50PF — C5 56 PF — R4 1.1K — R3 1.1K — R2 1.1K
J1 1 2 3 4 — C1 68 — +5V.



DWG. NO.	21005 D		
REV.	E.C.N.	DATE	REMARKS
1	15643	7-6-84	
2	—		
3	16280	10-16-84	UPDATED B/M
4	16335	10-25-84	
5	16577	2-5-85	
6	17135	4-16-85	
7	17700	7-23-85	
8	18488	10-18-85	
9	18571	11-12-85	ADDED C40 CHANGE R7+2 TO 1
10	18717	1-15-86	
11	19397	6-2-86	
12	20602	5 21 87	
13	21120	10 30 87	
14	21739	10 17 88	
15	29037	8-15-01	

REF. DES.	PART NO.	DESCRIPTION	QTY.
	9233	P.C. BD.	1
R17,32	8328	RES. 750K 1% RN60D	2
R53	6186	RES. 60.4K 1%	1
R2	500270	RES. 1.05K	1
Z1-4	6548	RESISTOR NETWORK, 10KΩ	4
	9439	HEAT SINK (REGULATORS)	2
VR2	11107	REG LM79M15CP 15V. NEG.	1
VR1	11108	REG LM78M15CP 15V. POS.	1
U10-12	6343	I.C., OP-07	3
U8	8433	74LS74	1
U6,7,9,13	8500	LF411	4
U4	8069	1413	1
U3,5	9375	OP11	2
U1,2	3806	I.C., LM311	2
R10	71077	RESISTOR, 2KΩ	1
R39	8307	RESISTOR, 5.61MΩ	1
R38,41	8148	POT., 20KΩ	2
R36,37	6189	RESISTOR, 604KΩ, .1%	2
R27,33	7992	22.1KΩ	2
R20,21	3490	6.98KΩ	2
R35	3483	3.48K	1
R7,11,13,16, 18,24,28,34	4621	10KΩ, .1%	8
R6,31	3975	100KΩ	2
R15,19,22,26	4627	44.2KΩ	4
R25,40,43, 48-52	7964	10K, 1%	8
R8,12,14,30	8567	49.9 K	4
R44,46	5079	255K	2
R45,47	8929	200KΩ 1%	2
R9	6173	14.7KΩ 1%	1
R3	4635	1KΩ 0.1%	1
R1,4,5,23	3486	RESISTOR, 4.99KΩ	4
R29	3488	RES 6.04K	1
R 42	7962	RES 1.5M	1
K1-5	71071	RELAY 1PDT	5
J2	9402	CONNECTOR,	1
D3,6-14	3997	DIODE IN4448	10
D1,2,4,5	3255	DIODE, IN100	4
C51	8776	CAPACITOR 100 MFD	1
C43	6525	100pf	1
20,50,	7986	22μF	6
C1,2,4,13,	"	"	
C40	5835	68PF	1
C33	7987	220 PF	1
C3,5-8,10-12, 14,16,19,21-32, 34-37,39,41,42	6270	.1μF	30
C9,15,17,18, 48,49	6975	CAPACITOR, 1μF	6

multi-amp CORPORATION
4271 BRONZE WAY, DALLAS, TEXAS 75237 (214) 333-3201

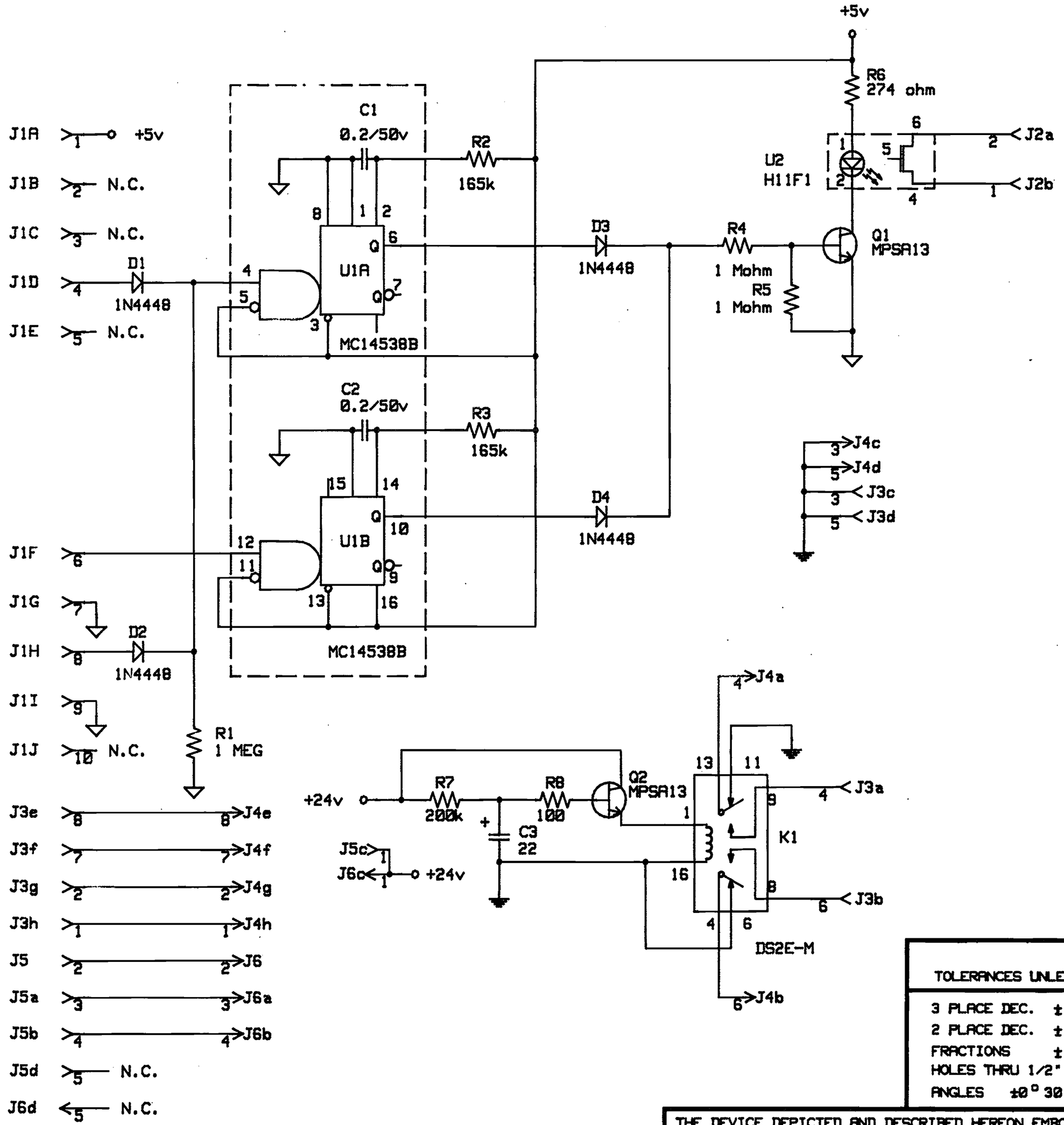
TOLERANCES: DECIMAL ±.010 FRACTIONAL ±1/64 UNLESS NOTED	DWN. ADF	APPD. PRR	SCALE: ∼
	CHKD.	DATE 4-30-84	SH. 1 OF 1
TITLE SCHEMATIC-P.C. BD, FEEDBACK/DISTORTION DET.			
PART NO. 9232	DWG. NO. 21005D	REV. 15	

THE DEVICE DEPICTED AND DESCRIBED HEREON EMBODIES PROPRIETARY DESIGN OWNED BY MULTI-AMP CORP. ALL DESIGN, MANUFACTURING, REPRODUCTION, SALES AND PATENT RIGHTS REGARDING THIS DEVICE OR DRAWING ARE RESERVED, EXCEPT WHERE EXPLICIT RIGHT IS GRANTED IN WRITING.

21005D

[redacted]

EASI FILE CORP. IRVINE, CA
EFH22



DWG. NO. 22621B			
REVISIONS			
REV	ECN	DATE	REMARKS
1	9/86	19790	

K1	8725	RELAY	1
Q1,2	6221	TRANSISTOR MPSA13 NPN DARL.	2
J6	8571	CONN MOLEX .156 5P HEADER STR.	1
C3	7986	CAP. MFD 22.0 35V	1
C1,C2	9968	CAP. MFD 0.2 50V MONO CER.	2
J3	10881	.156 8P HEADER 2145C TOP ENTRY	1
J2	10245	.047 2 PIN HEADER MOLEX	1
J1	8718	10 PIN HEADER 3M	1
J4	5369	.156 8P HEADER STRAIGHT	1
J5	10893	CONN MOLEX .156 5P 2145C TOP ENTRY	1
R8	7989	RES 0 100 1% 1/8W FILM	1
R7	8929	RES 200 1% 1/8W FILM	1
R6	7966	RES 0 274 1% 1/8W FILM	1
R1,4,5	6584	RES M 1.0 5% 1/4W	3
R2,3	6187	RES K 165 1% 1/8W RN55D	2
D1-4	3997	DIODE 1N4448	4
U2	10725	H11F1 OPTO-COUPLER	1
U1	6385	IC CMOS 4538B DUAL ONE SHOT	1
REF. DES.	PART NO.	DESCRIPTION	QTY.

TOLERANCES UNLESS NOTED

3 PLACE DEC. ± .005
2 PLACE DEC. ± .02
FRACTIONS ± 1/32
HOLES THRU 1/2" DIA. +.004 -.000
ANGLES ±0° 30'

THE DEVICE DEPICTED AND DESCRIBED HEREON EMBODIES PROPRIETARY DESIGN OWNED BY MULTI-AMP CORP. ALL DESIGN MANUFACTURING, REPRODUCTION, SALES AND PATENT RIGHTS REGARDING THIS DEVICE OR DRAWING ARE RESERVED, EXCEPT WHERE EXPLICIT RIGHT IS GRANTED IN WRITING

multi-amp
(214) 333-3201
4271 BRONZE WAY DALLAS, TEXAS 75237

DWN. RJ PARRISH	APPD. Paul Rupnow	SCALE NONE	
CHKD.	DATE 3/19/86	SH. 1 OF 1	

TITLE
SCHEMATIC GAIN CLAMP CKT & SOFT START

PART NO.	DWG. NO.	REV
10875	22621B	1

22621B
1 of 1

22993B EASI FILE CORP. IRVINE, CA EFH 22 REV 4

DWG. NO. 22993B

REVISIONS		
REV	ECN	DATE
A	21385	03/88
1	21519	06/88
2	21742	11/88
3	26265	05/91
4	24582	7-27-92

REF. DES.	PART NO.	QTY.
C1,C2	9431	2
R4	9398	1
R3	3470	1
	10989	1
J4	11396	1
J3	11110	1
J2	10962	1
J1	8571	1
T1	10990	1
D1,2	9258	2
R1,2	9532	2

multi-amp CORPORATION (214) 333-3201
4271 BRONZE WAY
DALLAS, TEXAS
75237

DWN. RJ PARRISH
CHKD.
APPD.
DATE 5-22-91

SCALE NONE
SH. 1 OF 1

TITLE SCHEMATIC INTERCONNECT -EPOCH 10

PART NO. 10988/11395
DWG. NO. 22993B
REV 4

TOLERANCES: UNLESS NOTED
3 PLACE DEC. +/- _____
2 PLACE DEC. +/- _____
FRACTIONS +/-1/32
HOLES THRU 1/2" DIA. +.004 -.000
ANGLES +/- 0 DEG 30 MIN.

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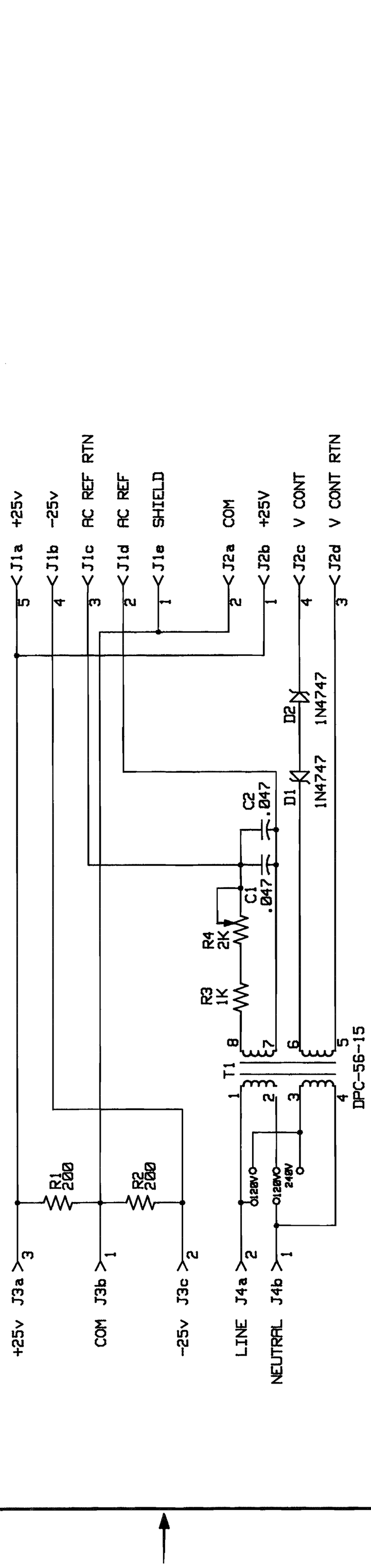


23379 D

EASI FILE CORP. IRVINE, CA EFH 22

1 OF 1

2

DWG. NO. 23379D

REV.	E.C.N.	DATE	REMARKS
1	21519	5-31-88	
2	23280	12 15 90	

PART N.O.

1. REF. BM-23383BM. W/D-19493 D
2. ITEMS MARKED----ARE MOUNTED ON CHASSIS. RELAYS MOUNTED W/ BRACKET.
3. FOR COMPONENT DESCRIPTION AND QTY. SEE B/M.

REF. DES	PART NO.
R35	3528
Q1	6221
L1,34	3455
L1	10224
R29	6259
R33	10221
K5	9499
R30	3484
R28	4297
R19	9398
D17-20	3255
T2	4699
T1	9181
TB3	238
TB2	165
TB1	8583
R21,22,23	9572
R50,R51	4638
R25,26	9406
R20	4632
R16-18	6181
R14,15	11142
R13-1,2	8750
R12	4621
R11	9030
R9	10223
R8,10	3434
R7,24,32	8730
R1-6	8725
K6-10	9207
K4	9208
K1,2,3	6966
BZ1	10962
J3	6626
J2,4	9403
J1	3997
D4-7,9-14	8051
D3	3073
D1,2,15,16	8120
CR1	7986
C2	6270
C4	9201
C3	6536
C1	4261
U3,4	9247
U2	8069
U1	

multi-amp CORPORATION
4271 BRONZE WAY, DALLAS, TEXAS 75237 (214) 333-3201

TOLERANCES: DECIMAL ±.010 FRACTIONAL ±1/64 UNLESS NOTED
DWN. RMD CHKD. APPD. DATE 1-29-88
SCALE: NONE SH. 1 OF 1

TITLE EPOCH10 OUTPUT SCHEMATIC

PART NO. 11146 DWG. NO. 23379D 2

THE DEVICE DEPICTED AND DESCRIBED HEREON EMBODIES PROPRIETARY DESIGN OWNED BY MULTI-AMP CORP. ALL DESIGN, MANUFACTURING, REPRODUCTION, SALES AND PATENT RIGHTS REGARDING THIS DEVICE OR DRAWING ARE RESERVED, EXCEPT WHERE EXPLICIT RIGHT IS GRANTED IN WRITING.

MADE FROM 19542D

TIMER START
TIMER START CONTACT
VOLTS APPLIED
COMMON
CONTINUITY
A.C. RETURN
A.C. VOLTS
+25V.
COMMON
I CHANNEL FRONT PANEL BINDING POST -OUTPUT
I CHANNEL FRONT PANEL BINDING POST -COMMON
E CHANNEL FRONT PANEL BINDING POST -COMMON
E CHANNEL FRONT PANEL BINDING POST -OUTPUT
TB1-6
TB1-8
R29 2.43Ω
3.125A
12.5A
25A
DISABLE
N.C.
N.O.
K1
K2
K10
K3
K4
K5
K6
K7
K8
K9
D1
D2
D3
D4
D5
D6
D7
D9
D10
D11
D12
D13
D14
D15
D16
D17-20
CR1
C1
C2
C4
R1
R2
R3
R4
R5
R6
R7
R24
R32
R35
Q1
K10
U2
U3
U4
SPARES
+5V.
R14
R15
E POWER AMP SIGNAL INPUT
I POWER AMP SIGNAL INPUT
TB1
TB2
TB3
PRIMARY
SECONDARY
T1
T2
R30
R13-1 0.4Ω
R13-2 0.4Ω
R12 0.02Ω
R21 100Ω
R22 100Ω
R23 100Ω
R26 0.1Ω
R51 0.1Ω
R25 0.1Ω
R50 0.1Ω
L1 R34
R33
R6 20K
R10 20K
R17 100K
R18 100K
R16 49.9K
R9 49.9K
R28 30.1K
R19 2K
R20 20K
R11 10K
40.00,150.0
300.0
25.00
12.50
12.5.25
150V.
40V.
CHASSIS GROUND NODE
U1
BZ1
TEST POINT
C3
+5V
E RANGE 1
ALARM
X2 E RANGE
I RANGE 1
I RANGE 2
I RANGE 3
TIMER START
VOLTS APPLIED
CONTINUITY
CURRENT CHANNEL FEEDBACK
RED
BK
SHIELD
J1
J2
J3
J4
U3

23579D 1 of 2 2

EASI FILE CORP. IRVINE, CA EFH 22

EF14DSP 06-12-1988 15:44

DWG. NO.	REVISIONS		
	REV	ECN	DATE
	1	21519	6-20-88

multi-amp CORPORATION
4271 BRONZE WAY DALLAS, TEXAS 75237 (214) 333-3201

ENGR. APPD. DATE 8-18-88

TITLE EPOCH10 FRONT PANEL SCHEMATIC

SHEET 1 OF 2

PART NO. 11232 DWG. NO. 23579D REV. 2

THE DEVICE DEPICTED AND DESCRIBED HEREIN EMBODIES PROPRIETARY DESIGN OWNED BY MULTI-AMP CORP. ALL DESIGN, MANUFACTURING, REPRODUCTION, SALES AND PATENT RIGHTS REGARDING THIS DEVICE OR DRAWING ARE RESERVED, EXCEPT WHERE EXPLICIT RIGHT IS GRANTED IN WRITING

TELEDYNE POST N34926

235790 2 of 2
EASI FILE CORP. IRVINE, CA EFH22

FPANELIE 08-12-1998_16: 18

multi-amp
CORPORATION 4271 BRONZE WAY DALLAS, TEXAS 75237 (214) 333-3201
TITLE EPCCH-10 FRONT PANEL SCHEMATIC
SHEET 2 OF 2
PART NO. 41232 DWG. NO. 235790 REV. 2

J4 ESWPOSX1 10 — S1 LSD — INCREASE_F_AMP
J4 ESWPOSX2 14 — S2 2ND — DECREASE_F_AMP
J4 ESWPOSX3 12 — S3 3RD — INCREASE_F_PHASE
J4 ESWPOSX4 13 — S4 MSD — DECREASE_F_PHASE
J4 ESWPOSY1 14 — S5 LSD — E_INIT_ENABLE
J4 ESWPOSY2 15 — S6 2ND — E_TAP_LOCK
J4 ESWPOSY3 16 — S7 3RD — E_ON
J4 ESWPOSY4 17 — S8 MSD
J4 ESWPOSY5 18

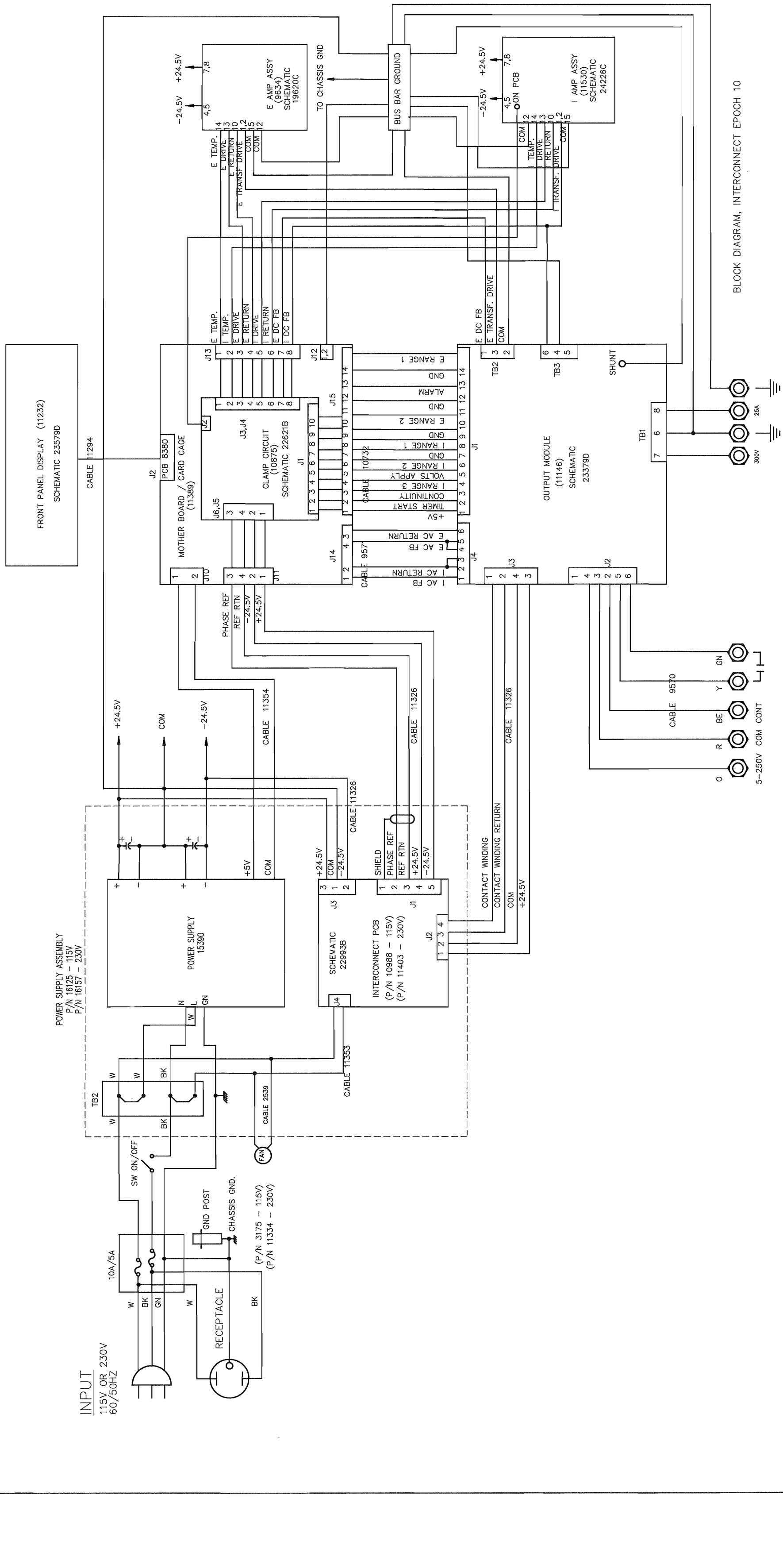
J4 ISWPOSX1 4 — S7 LSD — INCREASE_I_AMP
J4 ISWPOSX2 2 — S8 2ND — DECREASE_I_AMP
J4 ISWPOSX3 3 — S9 3RD — INCREASE_I_PHASE
J4 ISWPOSX4 4 — S10 MSD — DECREASE_I_PHASE
J4 ISWPOSY1 5 — S11 LSD — I_INIT_ENABLE
J4 ISWPOSY2 6 — S12 2ND — I_TAP_LOCK
J4 ISWPOSY3 7 — S13 3RD — I_ON
J4 ISWPOSY4 8 — S14 MSD
J4 ISWPOSY5 9 — S15 MSD
J4 ISWPOSY6 — S16 MSD

J4 CSWPOSX1 19 — S33 HORN
J4 CSWPOSX2 20 — S29 HARMONIC
J4 CSWPOSX3 21 — S34 MODE_SELECT
J4 CSWPOSX4 22 — S30 SELECT
J4 CSWPOSY1 23 — S31 INIT_CONTROL
J4 CSWPOSY2 24 — S33 HORN
J4 CSWPOSY3 25 — S35 FREG

23685D 1 of 2 6

EASI FILE CORP. IRVINE, CA EFH 22

REVISIONS				
REV	ECN	DESCRIPTION	DATE	APP'D
1	21519	SEE ECN	06/27/88	
2	21972	SEE ECN	03/11/89	
3	22137	SEE ECN	08/03/89	
4	24187	SEE ECN	02/03/92	
5	24424	SEE ECN	5/18/92	
6	26097	CHANGED PER ECN	12/12/94	



UNLESS OTHERWISE SPECIFIED	
ALL DIMENSIONS IN INCHES & INCLUDE APPLIED FINISH.	
TOLERANCE: 2 PL ± .030	
3 PL ± .010	
ANGLES ± 1°	
ALL SURFACES	REMOVE BURRS AND BREAK SHARP EDGES.
MATERIAL	

THE DEVICE DEPICTED AND DESCRIBED HEREON EMBODIES PROPRIETARY DESIGN, OWNED BY AVO. ALL DESIGN MANUFACTURING, REPRODUCTION, SALES, AND PATENT RIGHTS REGARDING THIS DEVICE OR DRAWING ARE RESERVED EXCEPT WHERE EXPLICIT RIGHT IS GRANTED IN WRITING.

SIGNATURES	DATE
DWN KG	12/12/94
CHK	
ENGR	
APVD	
RELEASE	
FILE NO 23685A06	
PART NO	

AVO MULTI-AMP® 4271 BRONZE WAY DALLAS, TEXAS 75237 (214) 330-3201

TITLE BLOCK DIAGRAM, INTERCONNECT, EPOCH 10

SIZE	DWG NO	REV
D	23685D	6
SCALE NTS	1=1	SHEET 1 OF 2
	34,22	

THIRD ANGLE PROJECTION

23685D

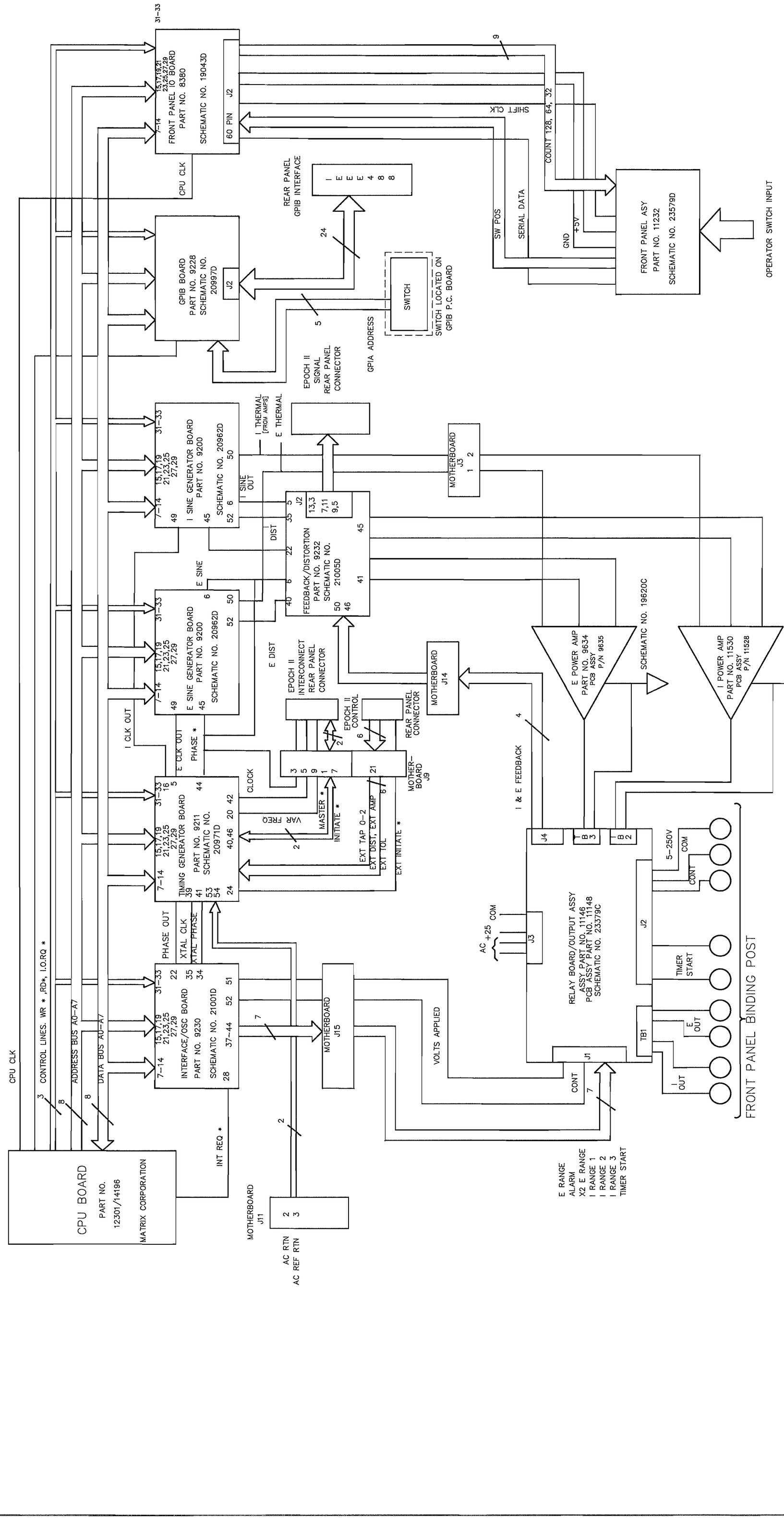
EASI FILE CORP. IRVINE, CA EFH 22

2 of 2

6

REVISIONS

REV	ECN	DESCRIPTION	DATE	APP'D



UNLESS OTHERWISE SPECIFIED	SIGNATURES	DATE
ALL DIMENSIONS IN INCHES & INCLUDE APPLIED FINISH.	DWN KG	12/12/94
TOLERANCE: 2 PL ± .030	CHK	
3 PL ± .010	ENGR	
ANGLES ± 1°	APVD	
REMOVE BURRS AND BREAK SHARP EDGES. ALL SURFACES 63	RELEASE	
MATERIAL	FILE NO 23685B06	
	PART NO	

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AVO MULTI-AMP®

4271 BRONZE WAY
DALLAS, TEXAS 75237
(214) 330-3201

TITLE BLOCK DIAGRAM, FLOWCHART, EPOCH 10

SIZE D | DWG NO 23685D | REV 6

SCALE NTS | 1=1 | 34,22 | SHEET 2 OF 2

THIRD ANGLE PROJECTION

DWG. NO. 23752A

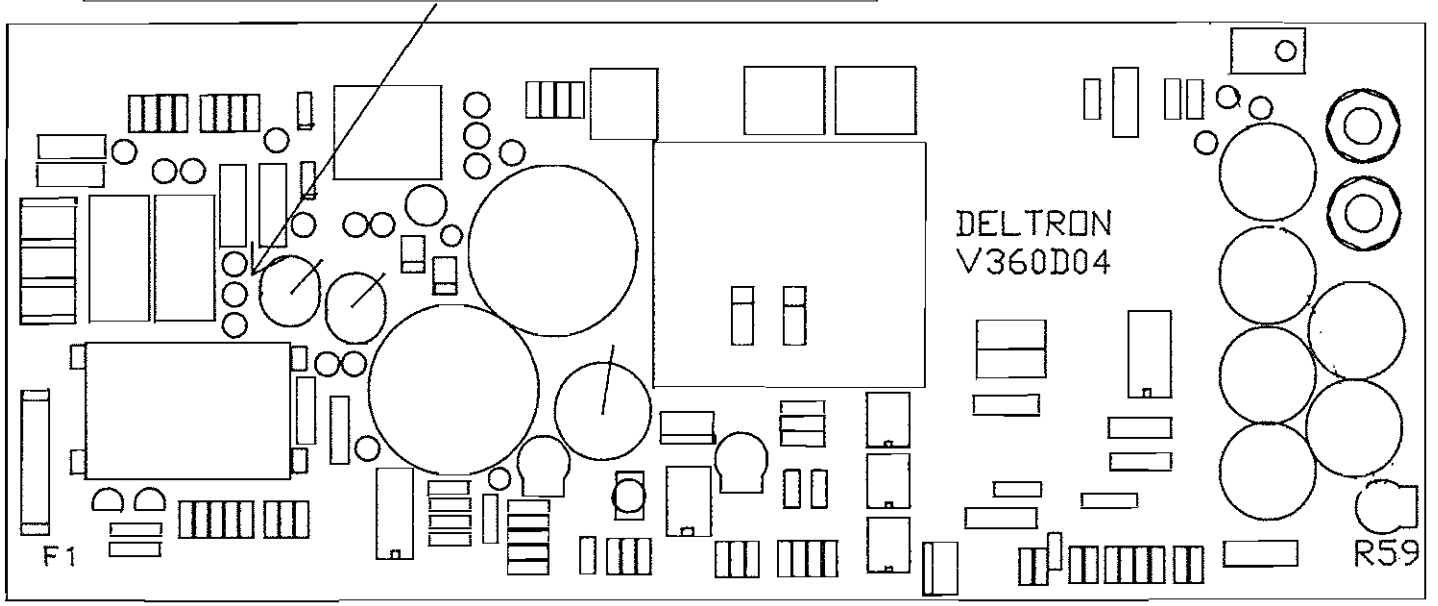
REVISIONS

REV	ECN	DATE
1	21519	5-31-88
2	21937	2-28-89
3	23552	4-4-91

SELECT VOLTAGE INPUT

E2 (110)
E1
E3
FOR 110V
JUMPER E1 TO E2

E2
E1
E3 (220)
FOR 220V
JUMPER E1 TO E3



INSTALL PN 11848
AT F1 FOR 230V. OPERATION.

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ENGR. E.C.	APPD. Paul Reynolds	DATE 11-30-87
TITLE EPOCH-10 VOLTAGE CHANGE INSTRUCTION		SHEET 1 OF 2
PART NO.	DWG. NO. 23752A	REV. 3

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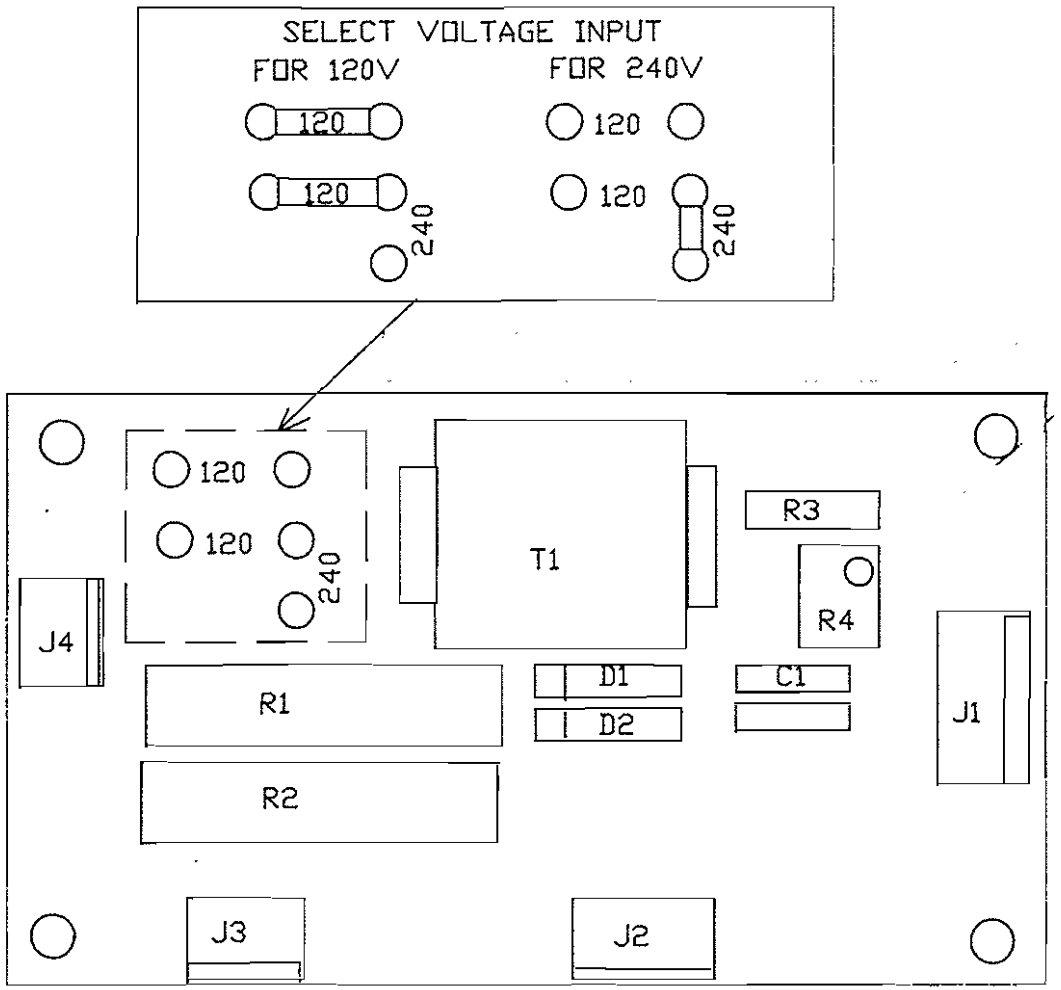
DWG. NO. 23752A



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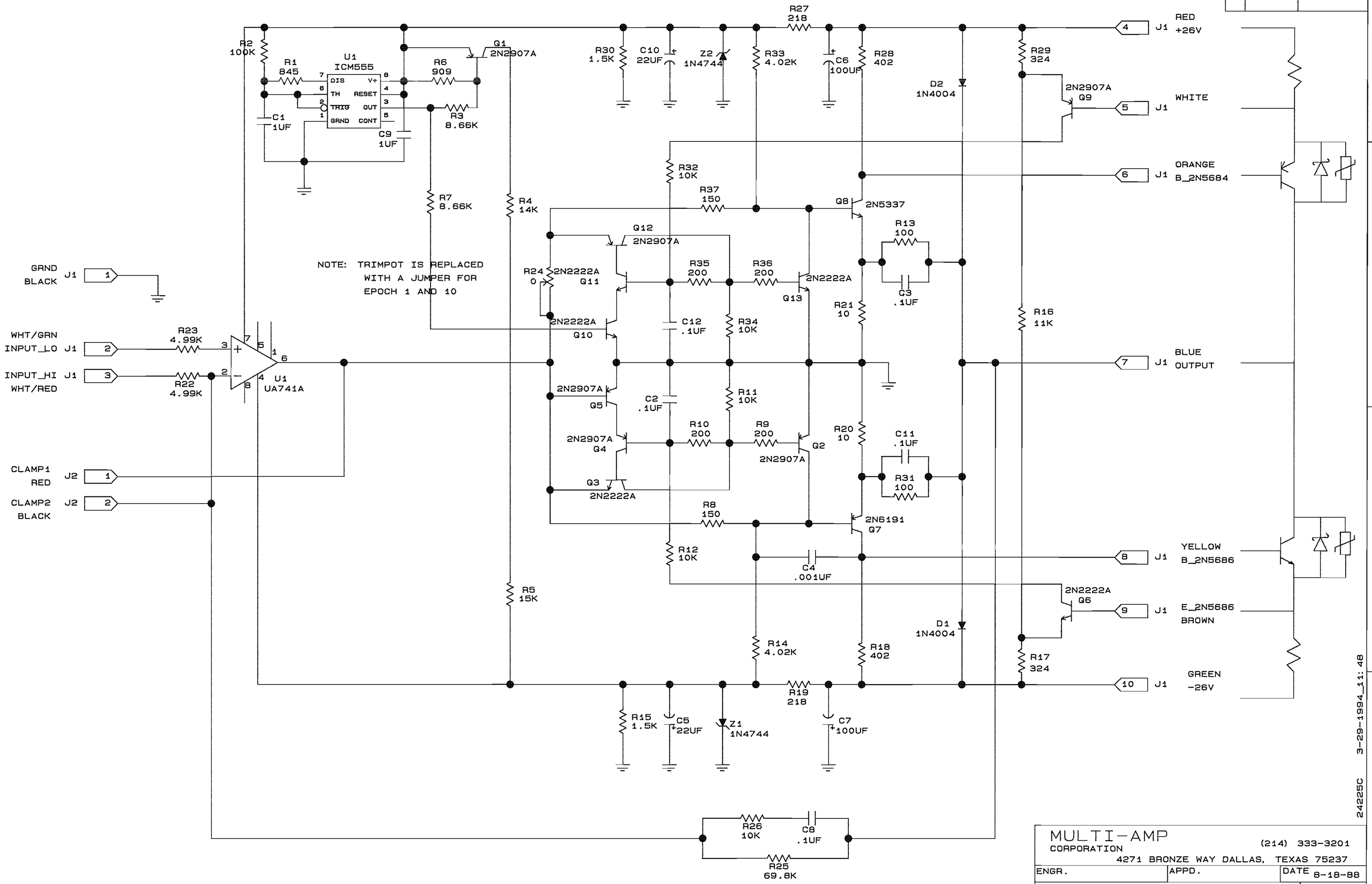
TITLE	SHEET
EPOCH-10 VOLTAGE CHANGE INSTRUCTION	2 OF 2

PART NO.	DWG. NO.	REV.
	23752A	3

DWG. NO.	24225C	
REVISIONS		
REV	ECN	DATE
1	23644	6-6-91
2	25328	11-3-93
3	25769	03/30/94



3-29-1994_11:48

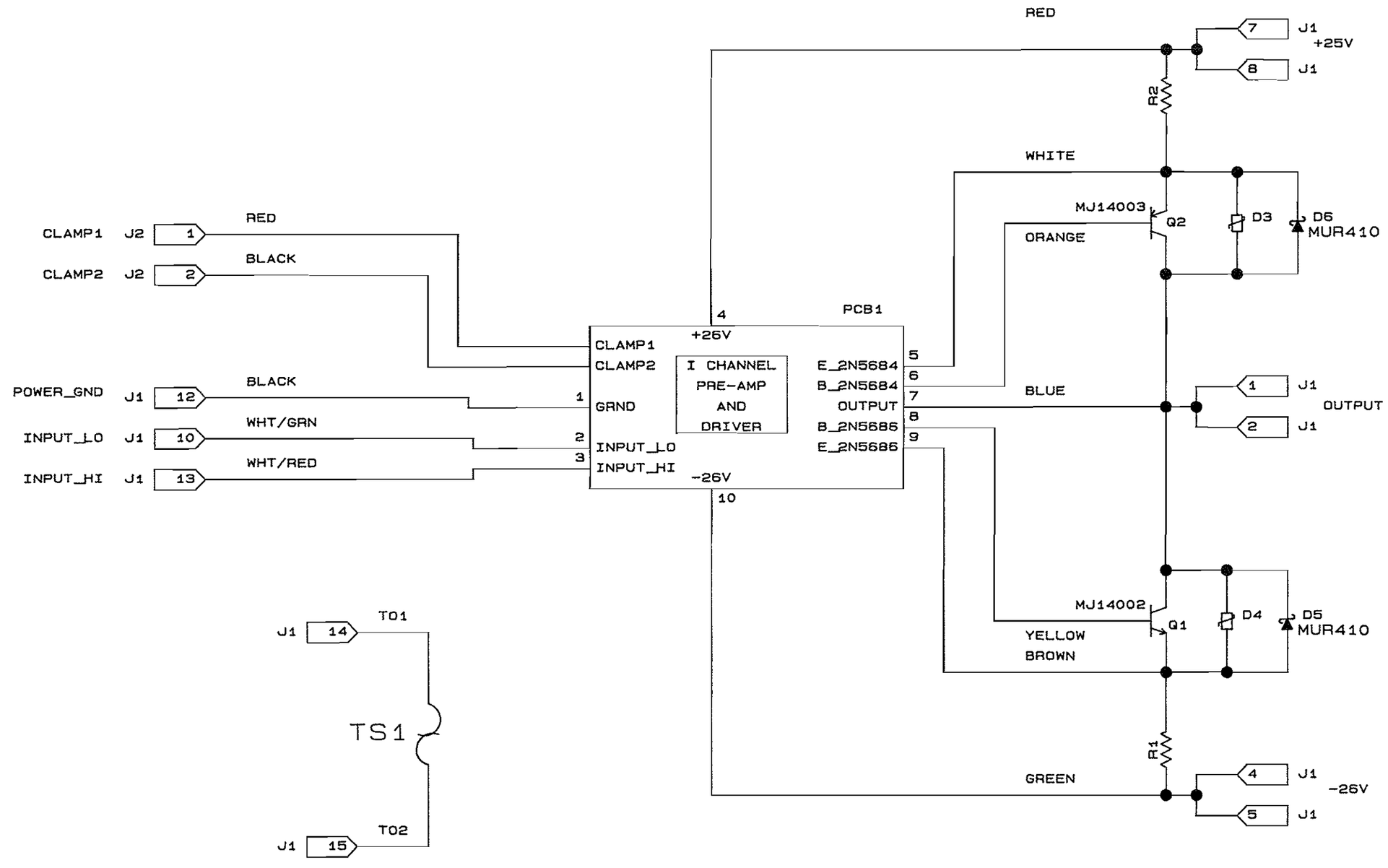
24225C

MULTI-AMP CORPORATION (214) 333-3201
4271 BRONZE WAY DALLAS, TEXAS 75237

ENGR.	APPD.	DATE 8-18-88
TITLE I CHANNEL PRE-AMP AND DRIVER, EPOCH 1 AND 10.		SHEET 1 OF 1
PART NO. 11528	DWG. NO. 24225C	REV. 3

PROPRIETARY

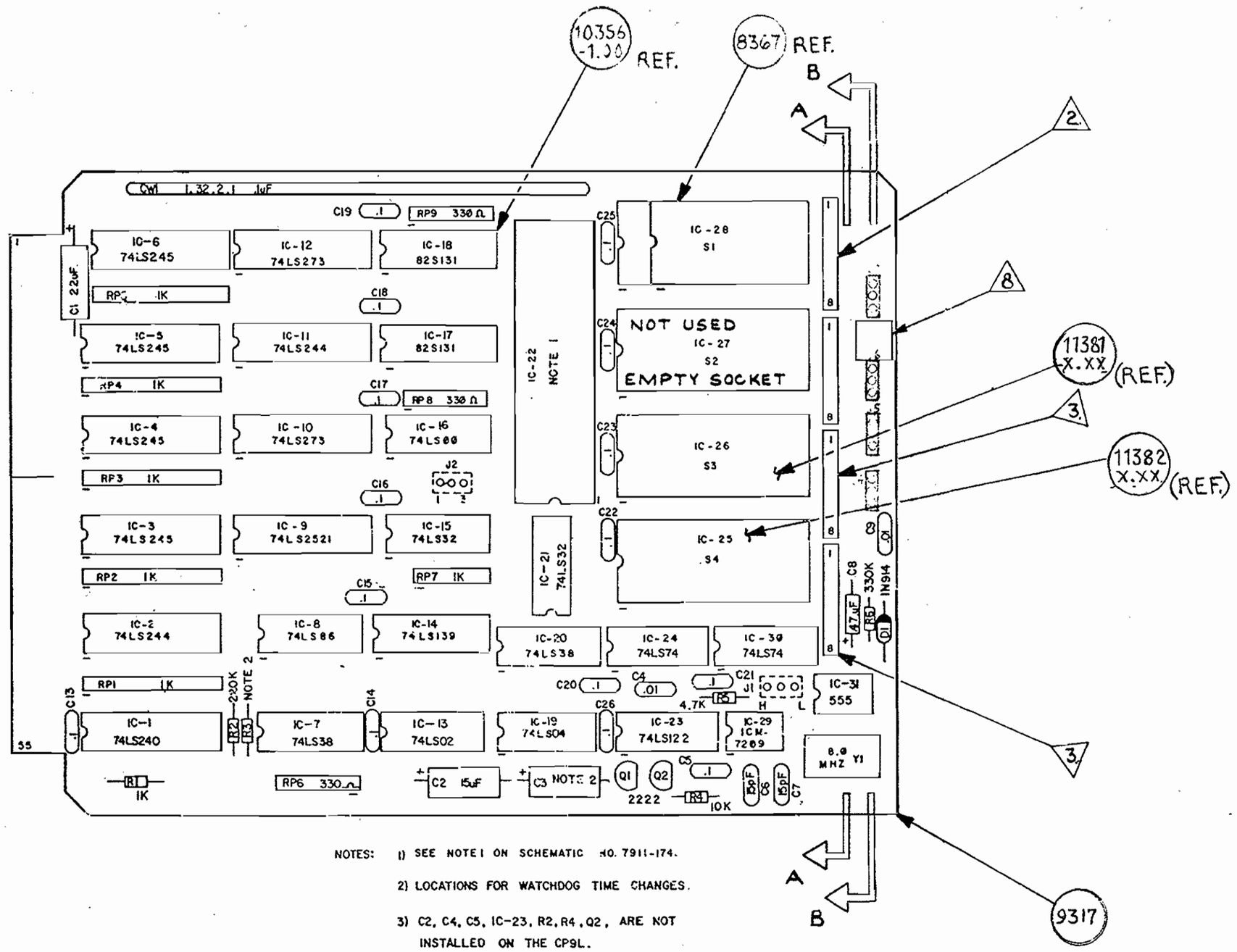
DWG. NO.	24226C	
REVISIONS		
REV	ECN	DATE
0	21659	8-26-88
1	23644	6-6-91



PROPRIETARY

MULTI-AMP CORPORATION		(214) 333-3201
4271 BRONZE WAY DALLAS, TEXAS 75237		
ENGR.	APPD.	DATE 6-6-91
TITLE CURRENT AMPLIFIER EPOCH-I.10		SHEET 1 OF 1
PART NO. 11530	DWG. NO. 24226C	REV. 1

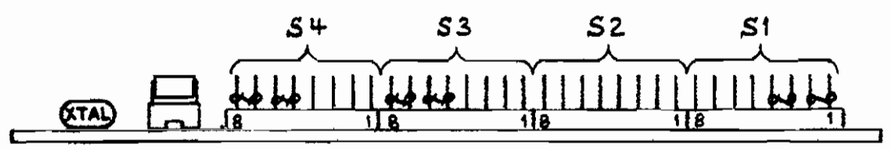
DWG. NO.	26479C		
REV.	E.C.N.	DATE	REMARKS



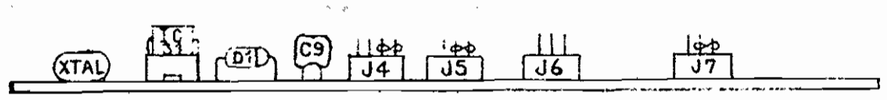
NOTES: 1) SEE NOTE 1 ON SCHEMATIC NO. 7911-174.

2) LOCATIONS FOR WATCHDOG TIME CHANGES.

3) C2, C4, C5, IC-23, R2, R4, Q2, ARE NOT INSTALLED ON THE CP9L.



SECTION A-A
ROTATED 90° CW



SECTION B-B
ROTATED 90° CW
REV. K P.C.BD.

NOTES:

1. I.C. 27 NOT USED.
2. INSTALL WIRE WRAP JUMPERS @ PIN 1 & 2 AND 3 & 4 FOR HM6116P-4 RAM. SECTION A-A DETAIL.
3. INSTALL WIRE WRAP JUMPERS @ PIN 5 & 6 AND 7 & 8 FOR 27128 EPROM. SECTION A-A DETAIL. FOR REV. "K" P.C.BD. ASSY. ALSO INSTALL JUMPER AS SHOWN IN SECTION B-B DETAIL.
5. I.C.18,28 VENDOR SUPPLIED. INSTALL AS SHOWN.
6. P.C. BD. MUST BE REV. "G" OR HIGHER.
7. JUMPER (P/N 9758) MAY BE USED IN LIEU OF WIRE WRAP JUMPERS.
8. WRITE PCB ASY REV NUMBER IN AREA SHOWN.

FOR COMPONENT DESCRIPTION & QTY. SEE B/M

multi-amp CORPORATION
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TOLERANCES: DECIMAL ±.010 FRACTIONAL ±1/64 UNLESS NOTED	DWN. RMD	APPD. Paul Burnett	SCALE: NONE
	CHKD.	DATE 1-31-90	SH. 1 OF 1

TITLE: ASSEMBLY—CPU PGMD EPOCH 10

PART NO.	DWG. NO.	
12301	26479C	Ø

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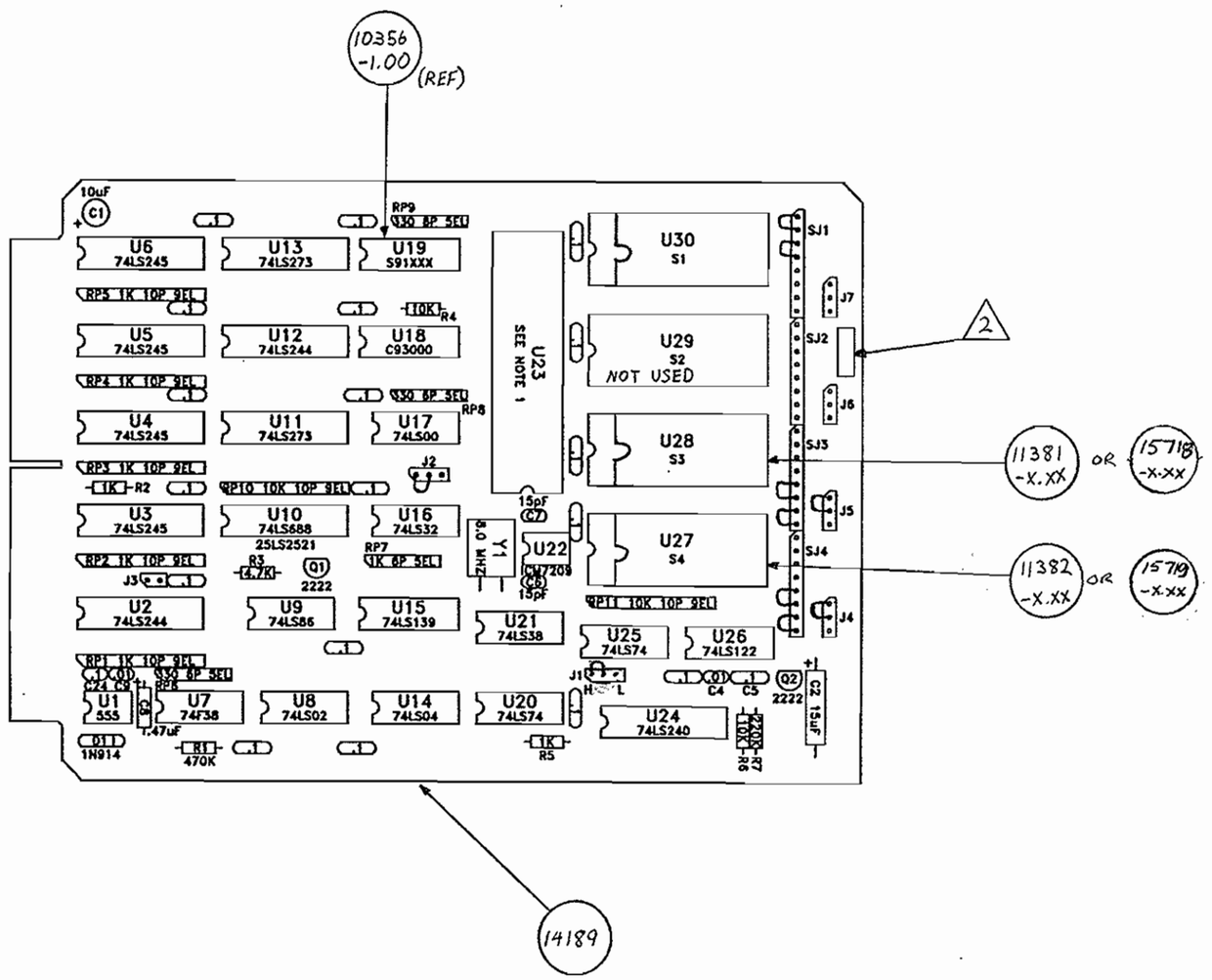
REVISIONS			
REV	ECN	DATE	APPROVED
1	24676	9-7-92	
2	25580	10-28-93	
3	25611	11-29-93	

JUMPER LIST
(USE P/N 9758)

J1 H-Middle
J2 1-2
J3 OPEN
J4 1-2
J5 1-2
J6 OPEN
J7 OPEN

SJ1 1-2,3-4
SJ2 OPEN
SJ3 5-6,7-8
SJ4 5-6,7-8



NOTES:

1 Refer to Jumper List and install or remove jumpers as needed

△2 Write PCB assembly rev number in area shown

3 U18, 19 and 30 are supplied by vendor

4 Vendor Model # is CP9B-MA2, refer to vendor packaging

5. TRIM COMPONENT LEADS TO 1/32".

FOR COMPONENT DESCRIPTION & QTY. SEE B/M

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UNLESS OTHERWISE SPECIFIED
ALL DIMENSIONS IN INCHES & INCLUDE APPLIED FINISH.
TOLERANCE: 2 PL ± .030
3 PL ± .010
ANGLES ± .25°
REMOVE BURRS AND BREAK SHARP EDGES.
ALL SURFACES 63
MATERIAL

SIGNATURES	DATE
DWN JDB	9-15-92
CHK	
ENGR	
APVD	
RELEASE	9/22/92
FILE NO	
PART NO	14196/15717

AVO MULTI-AMP® 4271 BRONZE WAY DALLAS, TEXAS 75237 (214) 330-3201

TITLE ASSEMBLY CPU PGMD EPOCH 10

SIZE C | DWG NO 27815C | REV 3

SCALE NTS | 1=1 22,17 | SHEET 1 OF 1