F2000 INSTRUCTION MANUAL

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DOBLE F2000 FAMILY
of
POWER SYSTEM PROTECTION APPARATUS TEST & CALIBRATION EQUIPMENT

NOTICE

This manual describes all members of the F2000 family of Protection Apparatus Test & Calibration Equipment equipped with and/or controlled by F2000 Firmware version r2.00 or higher. All F2100, F2200, F2500, and F2350 Test Instruments must be equipped with version r2.00 or higher for proper operation when connected to other F2000 instruments in a multiunit system. The F2000 Slave Sources will not operate properly if their controlling Test Instrument has a lower version. Verify each Test Instrument's Firmware revision level by pressing its SLAVE switch. The revision number is displayed in Source 1's AMPLITUDE window. Contact Doble's Customer Service Department at (617)926-4900, extension 321 for updated Firmware.

Firmware Revision R2.00 does not support IP with the F2500 source 1. This facility will be made available in a later revision that will be sent to all registered users.

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SECTION I
THE F2000 FAMILY

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FAMILY MEMBERS

The F2000 family of AC Power System Protection Apparatus Test and Calibration Equipment consists of an integrated group of precision Test Instruments, Slave Sources, related options, and associated remote control hardware and software. The Test Instruments and their Slaves provide highly accurate regulated ac and dc voltage and current test signals for analyzing, testing, and calibrating power system protection schemes and apparatus at both laboratory and in-service field locations. They can be operated individually or as a single integrated system, either manually from their front panel controls or remotely from a Doble Minicontroller or a Host Computer. The F2000 family members include:

- F2010 Minicontroller — Hand-held remote controller.
- F2100 Basic Test Instrument — 1 ac voltage and 1 ac current.
- F2200 Convertible Test Instrument — 1 ac voltage and 1 ac current or voltage.
- F2300 Slave High Power Current Source — 1 high power ac current.
- F2300A Slave High Power Current Source — 1 high power ac current.
- F2350 High Power Test Instrument — 1 high power ac current.
- F2410 Slave DC Test Source — 1 dc current or voltage plus 1 dc battery power supply.
- F2500 Dual Convertible Test Instrument - 1 ac current or voltage and 1 ac current or voltage

The four Test Instruments are self-contained units whose operation is controlled directly by internal microcomputers, and have all necessary manual controls and indicators on their front panels. Each provides one or two independent ac test signals from their internal sources. Up to six Test Instruments in any combination can be connected together to form a single networked system.

The three Slave Sources do not have internal microcomputers or front panel controls. Instead they are directly connected to a Test Instrument and use its microcomputer and one of its source's controls. When a Slave Source is in use the associated Test Instrument's source is not usable.

Each Test Instrument and its Slave operates at either a 50 Hz or 60 Hz base frequency, which can be synchronized to either the mains power or to a crystal oscillator. When two or more Test Instruments are connected together to form a multiunit system, one of them is designated the System MASTER and its frequency overrides the others, which are System SLAVES. Each source's frequency can be set to the MASTER frequency or its 2nd through 10th harmonic (except where the harmonic would exceed 600Hz). The MASTER frequency can be set from 25.00 to 99.99 Hz by either an F2010 Minicontroller or a Host Computer. The ac test signals are produced by patented Active Sources power amplifiers, and simulate the voltages and currents from potential transformers (PTs) and current transformers (CTs). These precision test signals may be used to investigate operating characteristics, set and check operating points, and calibrate all types and kinds of ac power system instruments that measure voltage (up to 300 V), current (up to 160 A), frequency (from 25 to 600 Hz), and/or phase angles (to 0.1 degree).

These devices include:

- Instrument Transformers
- Transducers and Meters
- Generation Protective Relays
- Distribution Protective Relays
- Transmission Protective Relays
- AC and DC Auxiliary Relays
- Static Terminals
- Complete Panelboards
- Fault Recorders
- Oscillographic Recorders
- Reclosers
- Generator Voltage Regulators and Govenors
- Automatic Synchronizers
- Motor Protection Equipment

FAMILY OPTIONS

A number of internal options are available that expand or improve the performance of F2000 family Test Instruments and their Slaves.

The internal options include:

- F2810 Fault Rotate — performs a 120° Δ or Y fault rotation.
- F2820 Δ Value/ Δ Time — provides rate-of-change capability for amplitude/phase angle/frequency. Used by the F2010 Minicontroller.
- F2825 Multiple Sources — allows up to 3 sources to be controlled simultaneously by the F2010 Minicontroller.
- F2835 Precision Phase Interface — ±0.1/0.25/0.5/1° zero crossing detection. Used with the FDF Dynamic Frequency Source.
- F2850 Precision Frequency Reference — increases frequency accuracy of all F2000 Instruments from ±0.01% to ±0.0005% using a temperature compensated crystal and oven. Recommended for all frequency relays, automatic synchronizer, and transducer testing.
- F2920 Precision Autosynchronizer Advance Time Measurement — the F2920 Precision Autosynchronizer Advance Time Measurement option is used to test auto-synchronizing relay's circuit breaker advance time. Traditional Test methods using chart recorders or oscilloscopes require subjective interpretation of waveforms leading to loss of repeatability and accuracy.
- F2860 Transient Waveform Generator — for replaying digital fault recorder records and E.M.T.P./A.T.P. power system simulations. The F2860 Transient Waveform Generator (TWG) provides 256,000, 16 bit samples of transient waveform coefficients per channel. The T.W.G. replaces the standard waveform generator board and requires TRANS2 Transient Simulation Software.
  * Stores multiple transients and long-term power swing simulations.
  * Transient data is stored until the Instrument is powered down, allowing one test plan to include Steady State, Pseudo Transient and Transient Simulation Tests using ProTesT III without reloading data.
  * The F2000 Timer can be started at any sample point in a transient record, for measuring relay operating time.

- F2870 Satellite Synchronizing Interface — the F2870 Satellite Synchronizing Interface synchronizes remotely located F2000 Systems using G.P.S. or G.O.E.S. Satellite receivers. Thed interface uses standard IREG B and 1 Hz timing signals used for synchronized end-to-end tests on unit protection schemes.
  - Used with SSIM II for State Simulation or TRANS II control for Transient Simulation.
  - Uses Standard satellite receiver outputs.
  - Reads time code form IRIG B signal and starts test as user-defined Test-Time-Of-Day.
  - Synchronizing to "Exact Second" 1 Hz clock pulse ensures phase coherency between remote test systems. Alternate "50/60 Hz Synch" and "Start" input for user-developed synchronizing schemes.
- F2910 Protest II Starter Kit — provides ProTesT II communication via the RS-232C port with an F2000 Host Computer.

FAMILY FEATURES

The F2000 family incorporates a number of special and sometimes unique features that enhance its operation. Some are standard in all members. Others are optional to reduce costs when they are not required. Options can be added to any instrument at any time, usually just by plugging in a printed circuit board (pcb) or inserting a module into an existing pcb.

Some of the major family features include the Modular Design, the Rugged Packaging, the Controls and Indicators, the Internal Microcomputer, the Active Sources amplifiers, AutoRange Mode, AutoSensE Operation, Fault Rotation, Parallel Sources, and Phase Interfaces.

Modular Design

The F2000 family is modular in concept and design so as to provide only those sources and capabilities that are needed for specific functions. This flexibility allows a wide range of capabilities, from a single Test Instrument that provides one or two test signal(s) under manual control up to a full system of 6 Test Instruments with 6 Slave Sources (plus 2 Slave DC Sources) and a remote host computer capable of simultaneously changing the amplitude and phase angle of 3 voltages and 3 high power currents at each end of a simulated 3ϕ transmission line on a cycle-by-cycle basis.

This modularity also aids portability by dividing the system into easily handled units. The Test Instruments and Slave Sources weigh just 52 to 65 pounds each, and have sturdy folding handles.

The Slave DC Source is only 23 pounds, while the Minicontroller is under 2 pounds.

Rugged Packaging

The F2000 family is ruggedly designed and constructed for safe transportation by truck over unpaved roads. Each unit passes the National Safe Transit Association (NSTA) test #1A, which requires no damage and full operability after 30,000 cycles that bounce the unit off of the shake table.

To pass the test requires a light but sturdy welded aluminum chassis with a monocoque case that withstands >20 G impact and >400 lb compression load, bolting all nonremovable components to the chassis then gluing or locking the bolts, locking all printed circuit boards in their cage, and using ribbon cables with locking connectors instead of wiring harnesses.

A molded two-piece case of high-impact shock-resistant ABS plastic provides protection from dust, dirt, and rain. Molded lands on the top and bottom lock units together when they are stacked, and rubber feet or optional castors on the back protect the unit when standing up. The top half is easily removed to provide access to the card cage.

A sliding door on the side provides easy access to the ON/off switch, sense input fuse, and all cable receptacles. The front cover, also of ABS, simply clips over the front panel.

A 3-position handle folds out of the way under the unit for stacking, and can be slid down to prop the unit up in a tilted position.

Controls & Displays

The Test Instruments use 3 types of dual-action switches for their manual controls. Paddle switches change values or states when they are pressed. Rocker switches provide individual ON/off control or ENABLE/disable their source, and indicating SYSTEM OUTPUT pushbuttons provide simultaneous on/off control of all enabled sources.

In Manual Mode, pressing a switch interrupts the microcomputer, which senses its new state and performs whatever action it specifies. In Remote Mode when under the control of ProTesT all the switches are disabled, — pressing any SOURCE or SYSTEM ON/OFF switch causes an abort, turning all sources off.

Light emitting diodes (LEDs) indicate the state of each condition or mode associated with their adjacent switches. A REMOTE indicator lights when the unit is in Remote Mode, and a High Voltage Indicator (under the lightning symbol) lights whenever a dangerous voltage is present at a source's output terminals.

Values and messages are shown by LED displays. The source displays always show the present values of their parameters except during startup, when an error occurs, and when the unit's configuration is requested. The timer's display is blank when off and shows messages during startup and when an error is detected. In the Sense Mode it shows the message "SENSE" when the sense input is asserted. In the Time Mode it shows the elapsed time since it was started (and stopped).

Internal Microcomputer

The Test Instruments use an internal microcomputer to control all their operations (and the operations of any attached Slave Sources). The microcomputer uses a high-speed 80186 microprocessor and data bus to transfer control and status information between the controls and indicators, external communication ports, and an input/output (I/O) controller for the various function modules and attached Slaves. All operations are directed by the firmware in a preprogrammed read-only memory (PROM). A random access memory (RAM) provides storage for remote control messages.

Active Sources® Amplifiers

All test signals are produced by Active Sources® power amplifiers. These provide a highly regulated ac or dc output of either voltage or current that is maintained regardless of any variation in the load impedance, the mains voltage or frequency, and/or the ambient temperature, within specified limits.

For normal temperatures (68–86°F) and at 50 or 60 Hz the outputs have an accuracy of 1/2 percent.

Amplitude is typically within ±0.25% (and always within ±0.5%) of the specified value. The phase angle is typically within ±0.2° (and always within ±0.5°) of the specified angle. Total harmonic distortion is typically within ±1% (and always within ±2%). Frequency is either at the mains frequency or within ±0.01% (±0.0005% with the F2850 Precision Frequency Reference option) of the set frequency.

AutoRange Mode

All F2000 ac sources use impedance matching transformers with tapped secondaries to couple their output to a load. Each tap provides a range from zero to some maximum amplitude at which full power is available. The taps are connected to the output terminals by relays that are controlled by the internal microcomputer.

When a source is in AutoRange Mode (Auto shown in its RANGE display), the lowest range is automatically selected by the amplitude value to provide the highest power signal.

The range is also automatically changed when the amplitude value is changed or ramped up into a higher range or down into a lower range. If the source is on, it is turned off for a few seconds while the relays change and the source stabilizes at the new power level.

AutoSensE Operation

AutoSensE finds the pickup, dropout, reach, and maximum torque angle of a relay quickly and easily. It operates in the Ramp Mode, when a parameter's value is being ramped up or down. When an external signal is sensed, in the Sense/Ramp mode, AutoSensE freezes the value of the parameter being ramped but leaves the sources on. In the Time/Ramp mode AutoSensE also stops the timer and turns sources off. AutoSensE operates with any parameter — amplitude, phase angle, or (with the Minicontroller) frequency.

Fault Rotate

The Fault Rotate option (F2810) speeds up 3-phase relay testing by reducing or eliminating the time, hazard, and possible errors in changing the leads each time a different phase is to be tested. It works with both Y configurations for ϕ–N faults and Open Δ configurations for ϕ–ϕ faults.

With Y configurations Fault Rotate uses 3 Y voltage sources (VA, VB, VC) and a single current (I1 or IP — from paralleled sources) or 3 Y currents (I1, I2, I3). It starts with a ϕ–N fault in phase A and changes the amplitudes and phase angles to effectively rotate the fault 120° counterclockwise into the next phase(s) each time the control is pressed.

With Open Δ configurations Fault Rotate uses 2 voltage sources (VA & VB) and a single current source (I1 or IP), and starts with a ϕ–ϕ fault between phases B and C (VA & I1). The fault is rotated 120° each time the control is pressed.

Parallel Sources

The I current sources in two or three F2100/F2200/F2500 Test Instruments can be operated as a single source by placing them in the Parallel Mode. When paralleled sources are connected to the load by identical leads (same length and gauge), the combined current is the sum from each source and the total power is the sum of each source.

Parallel sources are operated by the System MASTER. Its controls specify the frequency, range (and resolution), and phase angle of each source, and the total current from all the sources. The controls of the other sources are disabled, and their PHASE ANGLE and AMPLITUDE displays show PARALLEL to indicate their status.

Phase Interfaces

The Phase Interface options permit an F2100, F2200, or F2500 Test Instrument to evaluate, test, and calibrate automatic synchronizing relays.

The F2835 is for use by an F2100/F2200/F2500 in conjunction with a Doble Model FDF Dynamic Frequency Source. It produces a zero-crossing pulse from the voltage source's output that the FDF compares with a similar signal from its own output. The FDF's timer is started when the relay operates and stopped when the two pulses coincide to measure the breaker advance time directly.

The F2920 is for use by an F2200/F2500 with an F2010 Minicontroller. It produces and compares zero-crossing pulses from both voltage outputs. While the Minicontroller is controlling the frequency of one source and with the timer in the START mode, the instrument's timer is started by the relay when it operates and stopped when both pulses coincide.

Both the F2835 and F2845 Phase Interface options have switches allowing the zero crossing accuracy to be set to ± 1, 0.5, 0.25, or 0.1 degree.

TEST INSTRUMENTS

F2000 Test Instruments contain an internal microcomputer that controls one or two Active Sources power amplifiers; the front panel controls, displays, and indicators for each source; system controls and indicators; and an integrated Digital Timer.

Each source's displays show their current parameter values (or error or configuration messages), and their controls provide parameter and range control. (This same control is provided by a Host Computer when in Remote Mode.) The system indicators show the unit's current status.

An Interface Panel behind a sliding door on the right side contains:

A. The ON/off switch,
B. The mains power receptacle,
C. The Timer Protection fuse,
D. An IEEE-488 Bus receptacle,
E. Two SYNC receptacles,
F. An RS-232 serial port,
G. A D-232 serial port,
H. An F2300 slave interface, and
I. An F2410 interface.

The F2350 also has an F3 INTFC receptacle for interfacing with a Doble F3-S 3ϕ Test System.

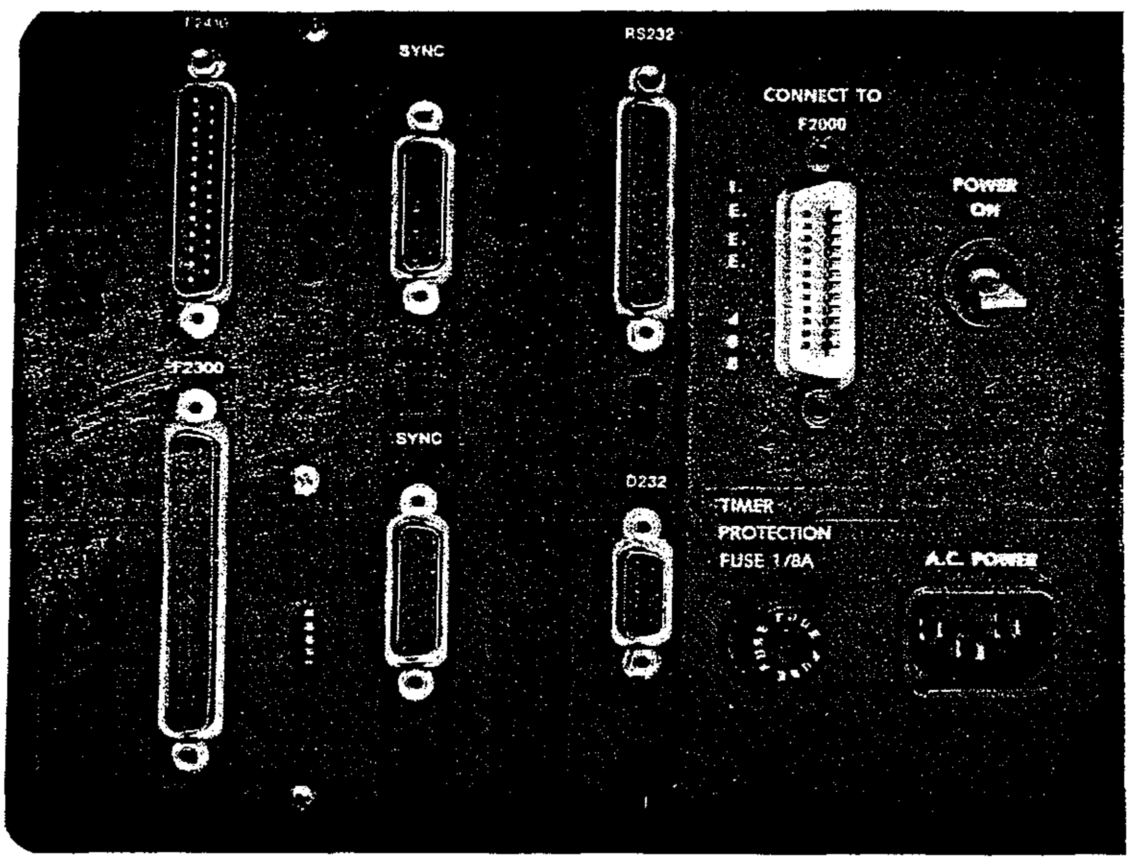


Figure 1-1. F2000 Interface Panel provides connections to other Test Instruments, Slave Sources, a Minicontroller, and a Host Computer.

F2100 BASIC TEST INSTRUMENT

The F2100 contains one ac voltage source (S1) and one ac current source (S2). The basic parameters of these sources are listed below. See Section VI for more complete specifications.

S1 Voltage Source

Ranges	75/150/300 volts.
Resolution	75 V = 0.01 V, 150 & 300 V = 0.1 V.
Power	80 VA @ maximum voltage in each range.
Power Factor	1 to ±0
Phase Angle	0 to ±360 degrees.
Angular Resolution	0.1°.
Frequency	Manual = 50 or 60 Hz, or 2nd thru 10th harmonic; Remote = 25 to 600 Hz.

S2 Current Source

Ranges	3.25/13/26 amperes.
Resolution	3.25 A = 0.001, 13 & 26 A = 0.01.
Power	105 VA @ maximum current in each range.
Power Factor	1 to ±0 with dc return).
Phase Angle	0 to ±360 degrees.
Angular Resolution	0.1°.
Frequency	Manual = 50 or 60 Hz, or 2nd thru 10th harmonic; Remote = 25 to 600 Hz.

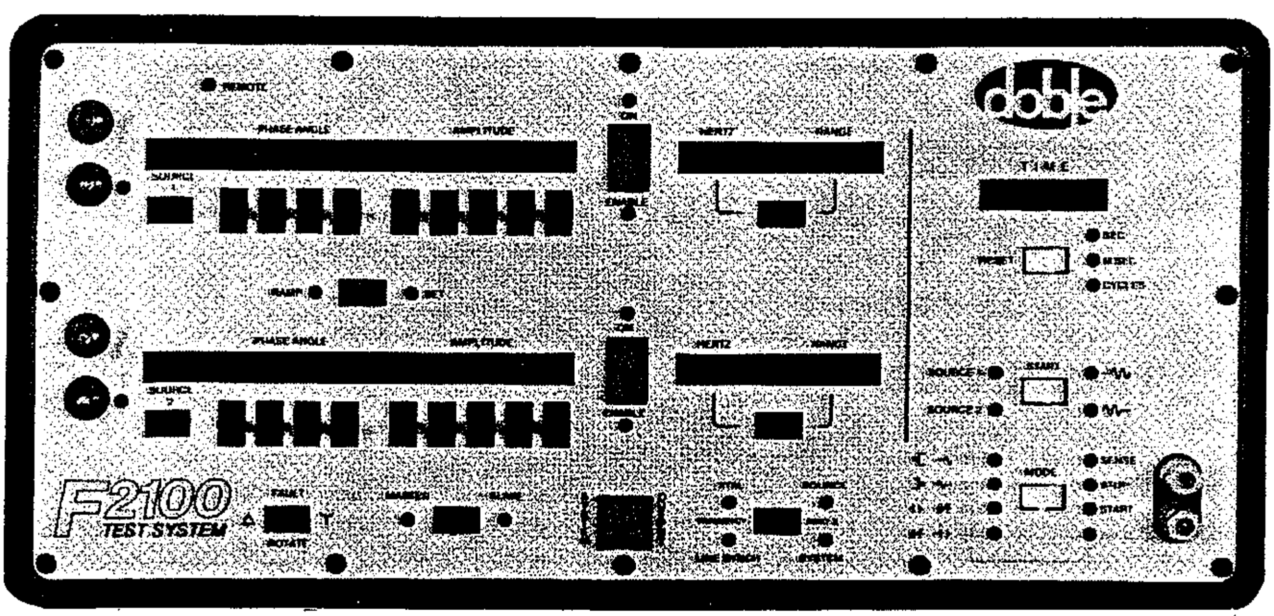


Figure 1–2. F2100 Basic Test Instrument.

F2200 CONVERTIBLE TEST INSTRUMENT

The F2200 contains one ac voltage source (S1) and one ac convertible source (S2) that can provide an ac current or another ac voltage. The basic parameters of theses sources are listed below. See Section VI for more complete specifications.

S1 & S2 Voltage Sources

Ranges .... 75/150/300 volts.
Resolution .... 75 V = 0.01 V, 150 & 300 V = 0.1 V.
Power .... 80 VA @ maximum voltage in each range.
Power Factor .... 1 to ±0
Phase Angle .... 0 to ±360 degrees.
Angular Resolution .... 0.1°.
Frequency .... Manual = 50 or 60 Hz, or 2nd thru 10th harmonic;Remote = 25 to 600 Hz.

S2 Current Source

Ranges .... 3.25/13/26 amperes.
Resolution .... 3.25 A = 0.001 A, 13 & 26 A = 0.01 A.
Power .... 105 VA @ maximum current in each range.
Power Factor .... 1 to ±0 (with dc return).
Phase Angle .... 0 to ±360 degrees.
Angular Resolution .... 0.1°.
Frequency .... Manual = 50 or 60 Hz, or 2nd thru 10th harmonic;Remote = 25 to 600 Hz.

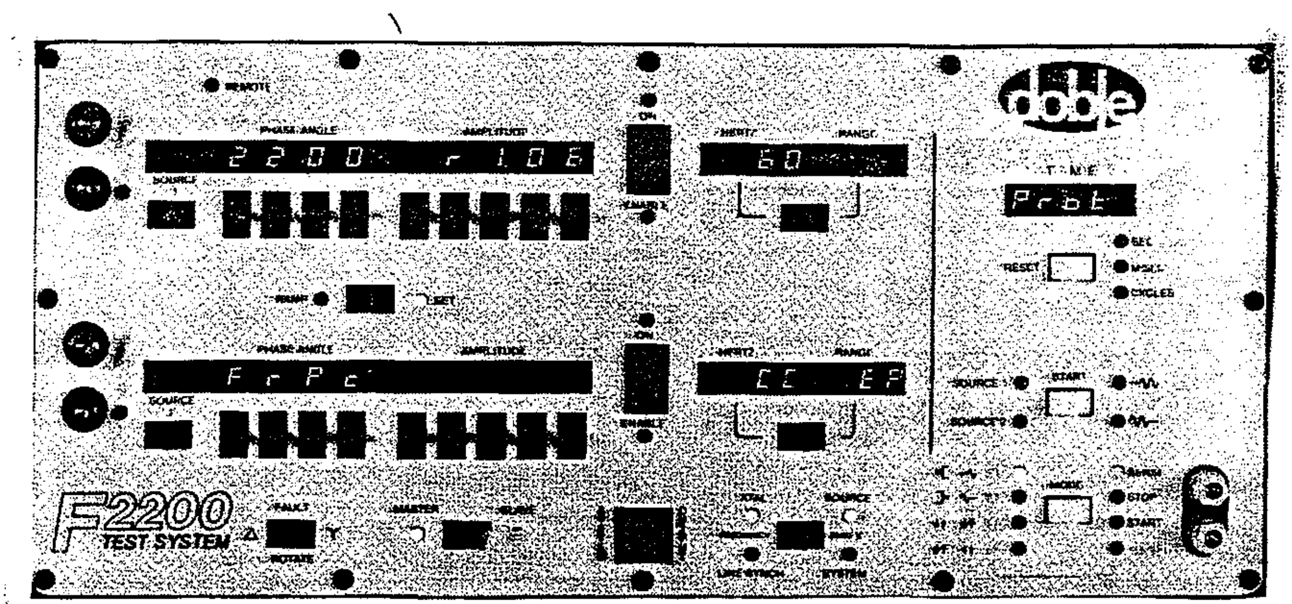


Figure 1-3. F2200 Convertible Test Instrument.
Showing Instrument Configuration Indication Initiated by Slave Position of Master/Slave Paddle Switch.

F2500 DUAL CONVERTIBLE TEST INSTRUMENT

The F2500 contains two ac convertible sources (S1 and S2), either or both of which can provide an ac current or ac voltage. The basic parameters of theses sources are listed below. See Section VI for more complete specifications.

S1 & S2 as Voltage Sources

Ranges .... 75/150/300 volts.
Resolution .... 75 V = 0.01 V, 150 & 300 V = 0.1 V.
Power .... 80 VA @ maximum voltage in each range.
Power Factor .... 1 to ±0

S1 as Current Source

Ranges .... 2.25/9/18 amperes.
Resolution .... 2.25 A = 0.001 A, 9 & 18 A = 0.01 A.
Power .... 72 VA @ maximum current in each range.
Power Factor .... 0 to ±1 (with dc return).

S2 as Current Source

Ranges .... 3.25/13/26 amperes.
Resolution .... 3.25 A = 0.001 A, 13 & 26 A = 0.01 A.
Power .... 105 VA @ maximum current in each range.
Power Factor .... 0 to ±1 (with dc return).

Both Sources

Phase Angle .... 0 to ±360 degrees.
Angular Resolution .... 0.1°.
Frequency .... Manual = 50 or 60 Hz, or 2nd thru 10th harmonic;Remote = 25 to 600 Hz.

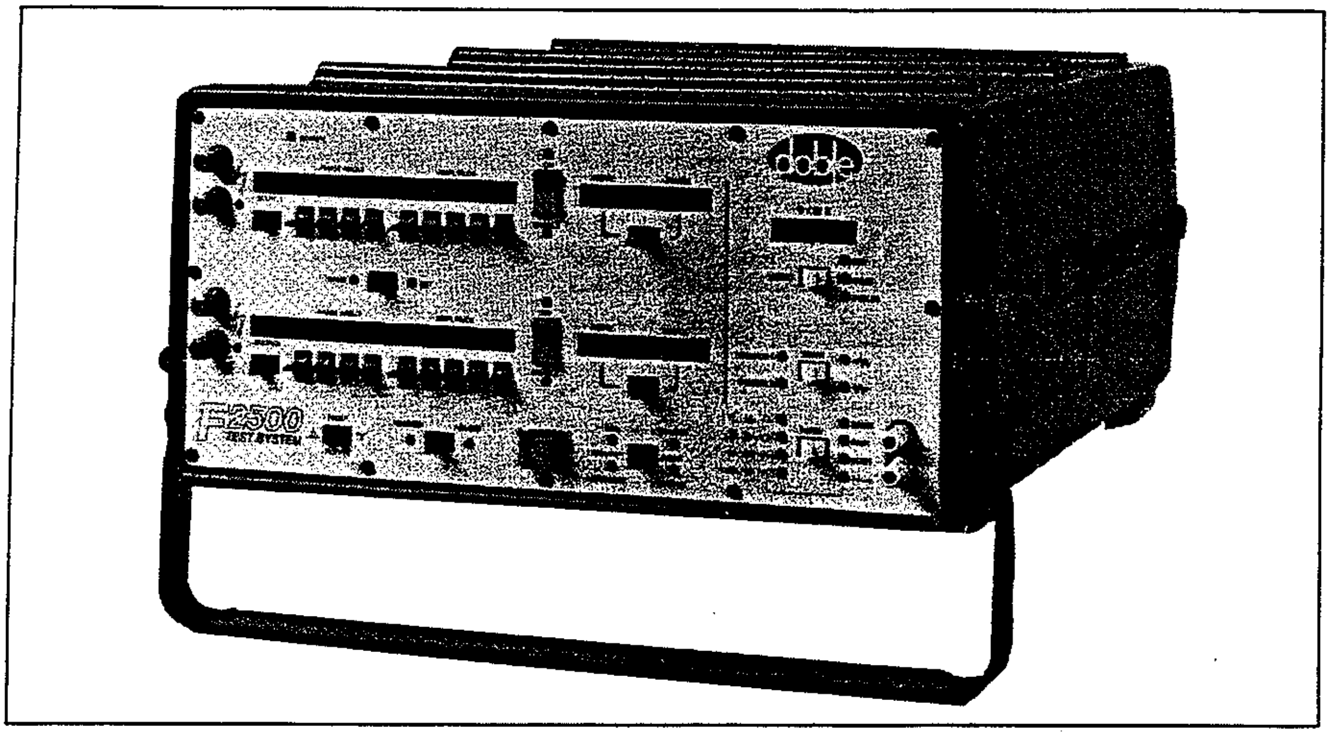


Figure 1-4. F2500 Dual Convertible Test Instrument.

F2350 HIGH POWER TEST INSTRUMENT

The F2350 contains a single high-power ac current source, S1. It can provide an ac current of up to 300 or 500 VA rms in each of 10 ranges. Up to 2100 VA peak inductive power is available for high burden inductive loads. The basic parameters of this source are listed below. See Section VI for complete specifications.

S1 High Current Source

Ranges .... 5/10/15/20/25/30/40/50/80/160 amperes.

Selection .... Manual or AutoRange.

Resolution .... 5 A = 0.01, 10 to 50 A = 0.01 A, 80 & 160 A = 0.1 A.

Power .... L = 300 VA, H = 500 VA rms @ maximum current in each range.
2100 VA peak inductive power in each range.

Power Factor .... 1 to ±0, dc return required.

Phase Angle & Resolution .... 0 to ±360 degrees @ 0.1°.

Frequency .... Manual = 50 or 60 Hz, or 2nd thru 10th harmonic; Remote = 25 to 600 Hz.

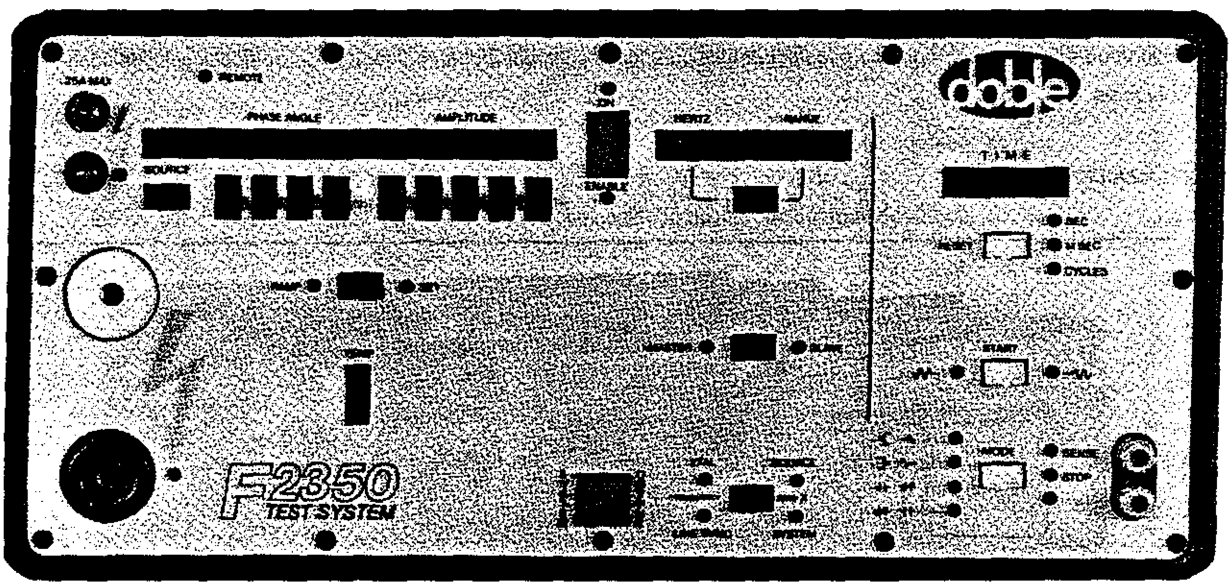


Figure 1-5. F2350 High Power Test Instrument.

SLAVE SOURCES

An F2000 Slave Source is connected directly to an F2100 or F2200 Test Instrument, and is operated by the Test Instrument's microcomputer and one of its source's controls (which disables that source when the Slave is selected). The F2410 Slave DC Test Source provides 48, 125, or 250 volt dc power, and a dc voltage or current for testing auxiliary relays.

The F2300 and F2300A Slave High Power Sources provide up to 160 A at 300 or 500 VA rms. The F2300 uses the same case and Active Sources amplifier as the F2350, and has the same 10 ranges. The F2300A uses the F2's high power Active Sources amplifier and case, and has six ranges that are manually selected by a Rotary Range Switch on its front panel.

F2410 SLAVE DC TEST SOURCE

The F2410 Slave DC Test Source contains an independent, manually-controlled Battery Simulator (BAT) that provides either 48, 125, or 250 volts dc power; and Slave DC Voltage and Current Sources that are powered and controlled by an F2100/F2200 ac voltage or current source. The unit's basic parameters are listed below. See Section VI for more complete specifications.

Battery Simulator

Voltage	48/125/250 volts.
Current	48V = ≤1.3 A, 125V = ≤0.5 A, 250V = ≤0.25 A.
Power	62.5 watts.

DC Voltage Source

Ranges	7.5–75/15–150/30–300 volts.
Resolution	75V = 0.01 V, 150V & 300V = 0.1 V.
Compliance Current	75V = ≤1.07 A, 150V = 0.53 A, 300V =≤0.266 A.
Power	80 watts.

DC Current Source

Range	0–3.25 amperes.
Resolution	0.001 A.
Compliance Voltage	≤18.5 V.
Power	60 watts.

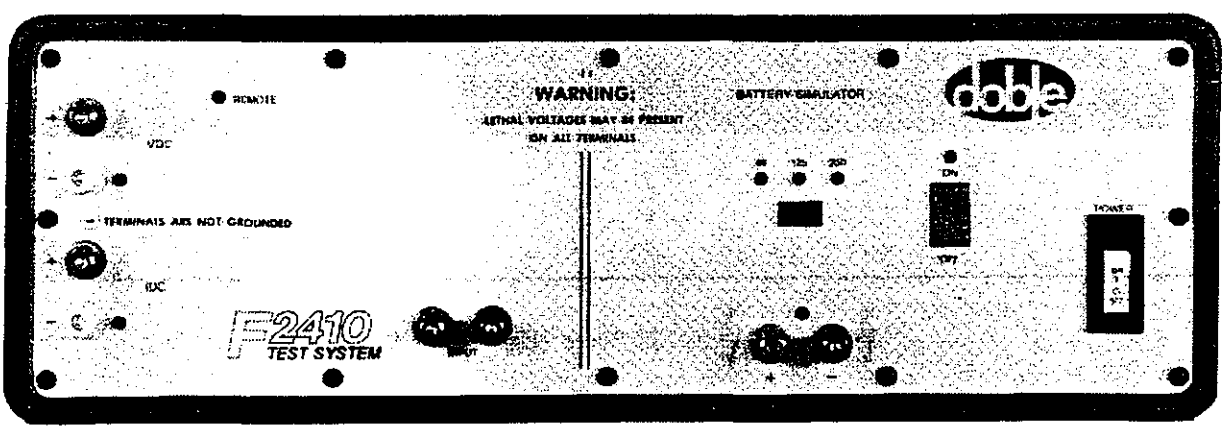


Figure 1-6. F2410 Slave DC Test Source.

F2300 SLAVE HIGH POWER CURRENT SOURCE

The F2300 contains a single Active Sources power amplifier that can provide an ac current of up to 300 or 500 VA rms in 10 ranges. Up to 2100 VA peak inductive power is available for high burden inductive loads. It is controlled by either source of the F2100/F2200 Master it is connected to.

The basic parameters of this source are listed below. See Section VI for more complete specifications.

High Current Source

Ranges .... 5/10/15/20/25/30/40/50/80/160 amperes.
Selection .... Manual or AutoRange.
Resolution .... 5 A = 0.01, 10 to 50 A = 0.01 A, 80 & 160 A = 0.1 A.
Power .... L = 300 VA, H = 500 VA rms @ maximum current in each range.
2100 VA peak inductive power in each range.
Power Factor .... 1 to ±0, dc return required.
Phase Angle & Resolution .... 0 to ±360 degrees @ 0.1°.
Frequency .... Manual = 50 or 60 Hz, or 2nd thru 10th harmonic; Remote = 25 to 600 Hz.

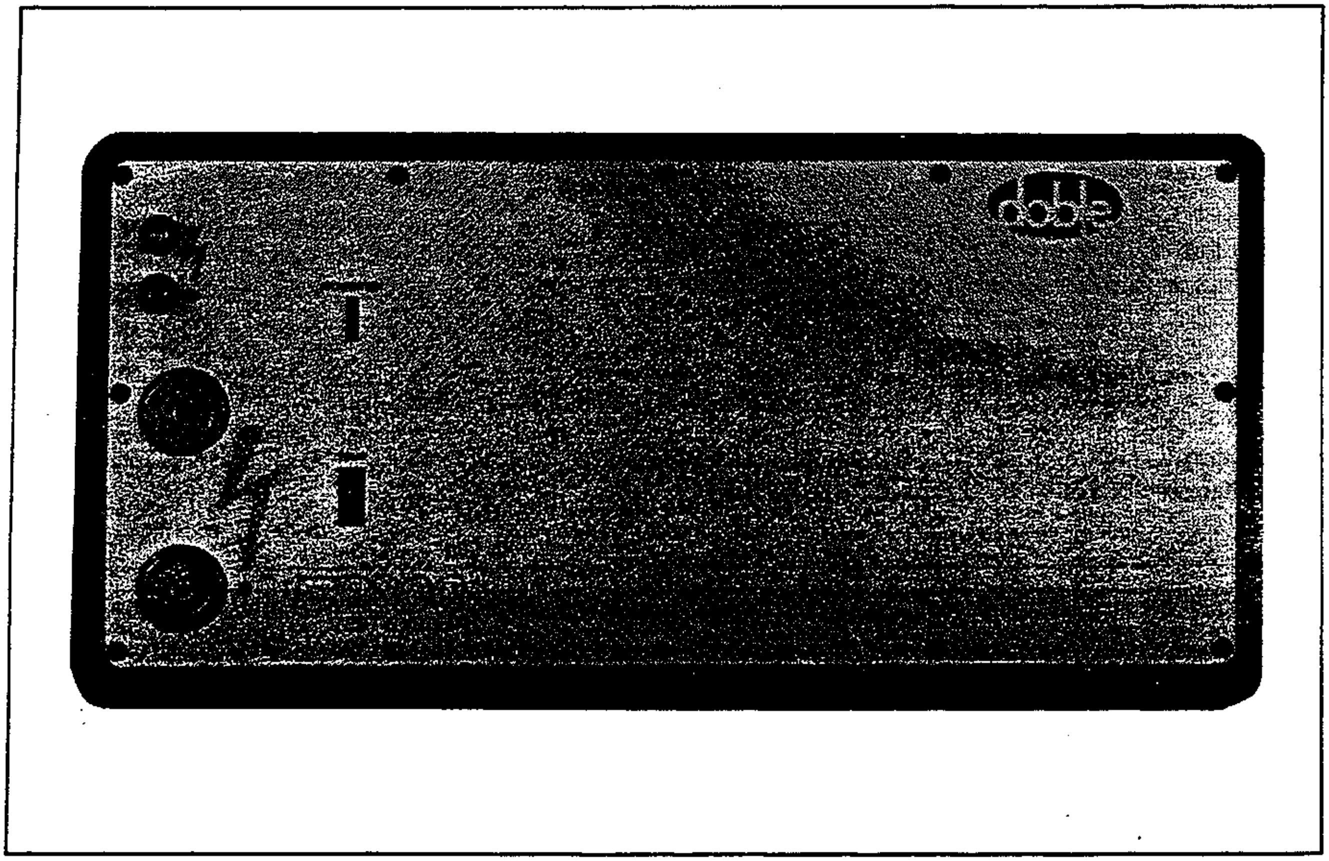


Figure 1-7. F2300 Slave High Power Source.

F2300A SLAVE HIGH POWER CURRENT SOURCE

The F2300A contains a single high–power Active Sources amplifier that can provide an ac current of up to 300 or 500 VA rms in each of 6 ranges. Up to 2100 VA peak inductive power is available for low impedance inductive loads. It is controlled by either of the F2100/F2200 sources it is connected to.

Ranges are selected manually by a Rotary Range Switch.

The basic parameters of this source are listed below. See Section VI for more complete specifications.

High Current Source

Ranges .... 5/15/30/45/70/160 amperes.

Selection .... Rotary Range Switch.

Resolution .... 5 to 45 A = 0.01 A, 70 & 160 A = 0.1 A.

Power .... L = 300 VA, H = 500 VA rms @ maximum current in each range.
2100 VA peak inductive power in each range.

Power Factor .... 1 to ±0, dc return required.

Phase Angle & Resolution .... 0 to ±360 degrees @ 0.1°.

Frequency .... Manual = 50 or 60 Hz, or 2nd thru 10th harmonic; Remote = 25 to 600 Hz.

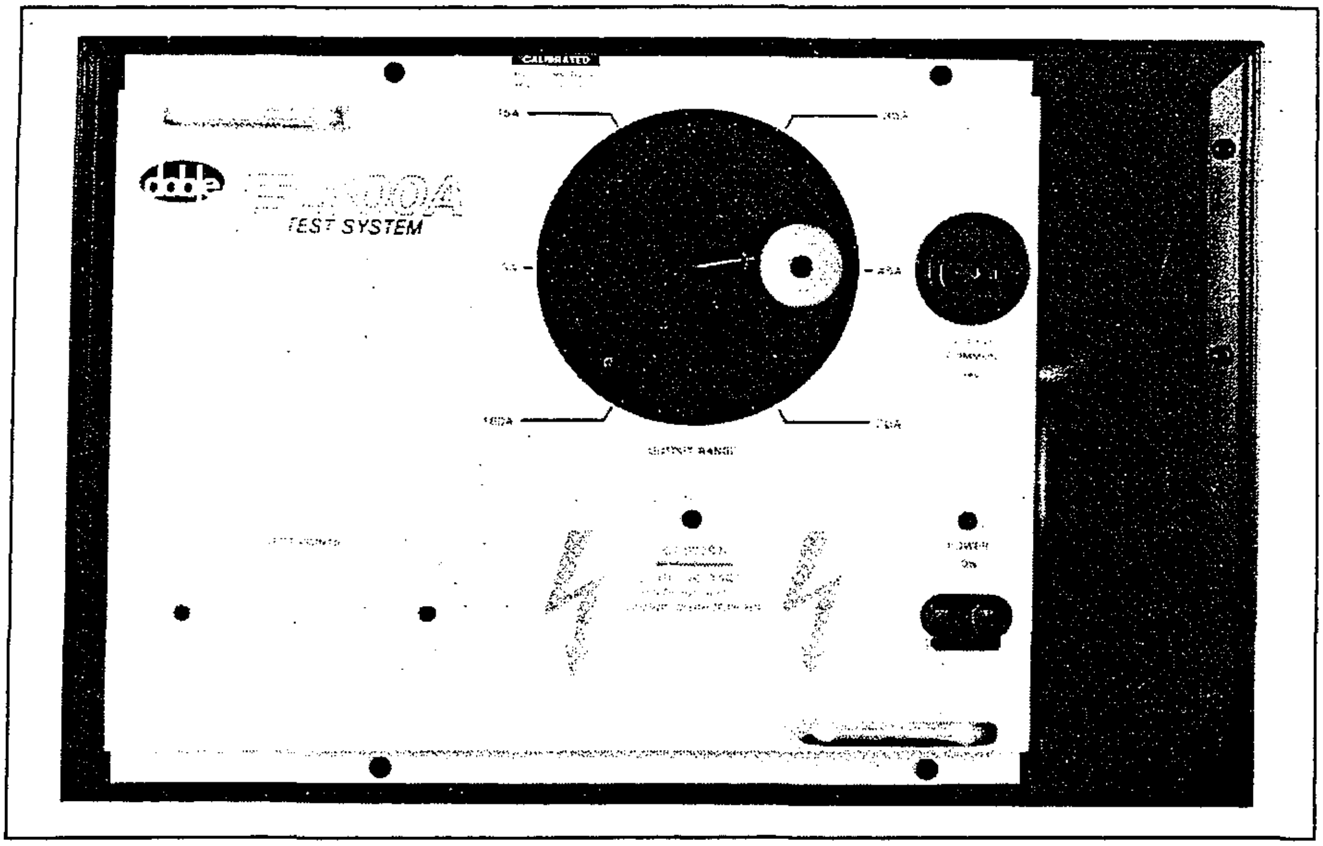


Figure 1–8. F2300A Slave High Power Source.

MULTIUNIT SYSTEMS

The members of the F2000 family are easily connected together to form a single multiunit system with a number of sources for testing multiphase protective relays and system protection schemes. Test Instruments are connected to each other by two cables in daisy-chain fashion which form a multidrop network. These are an IEEE-488 General Purpose Information Bus (GPIB) and an F2000 SYNC Bus.

A Slave Source is connected to its Test Instrument by a control cable, and operates as an extension of the Master. The F2010 Minicontroller plugs directly into the D-232 port of the Test Instrument it controls (the System MASTER). A Host Computer plugs into any Test Instrument's RS-232C port. Figure 1-9 shows how a typical multiunit system configuration is connected.

System Communication

The firmware used by the microcomputers controls communication between Test Instruments over the IEEE 488 Bus, using a special language and communications protocol called DobleCoL. Any Test Instrument may broadcast a message over the bus to all the other Test Instruments (and their Slaves) at any time. Only the unit or units addressed in the message responds, and performs whatever action is specified or required. The message may indicate the status of a source or unit, inform the other Test Instruments of an error condition, tell a source or sources to change a parameter value or set its turnon mode on or off, etc.

One of the Test Instruments must be designated the System MASTER to coordinate and synchronize the actions of the others. The System MASTER replaces the other units' clock signals and timing reference with its own, transmitting these to the other Test Instruments on the SYNC Cable. It thus supplies the base frequency and reference signals for the entire system.

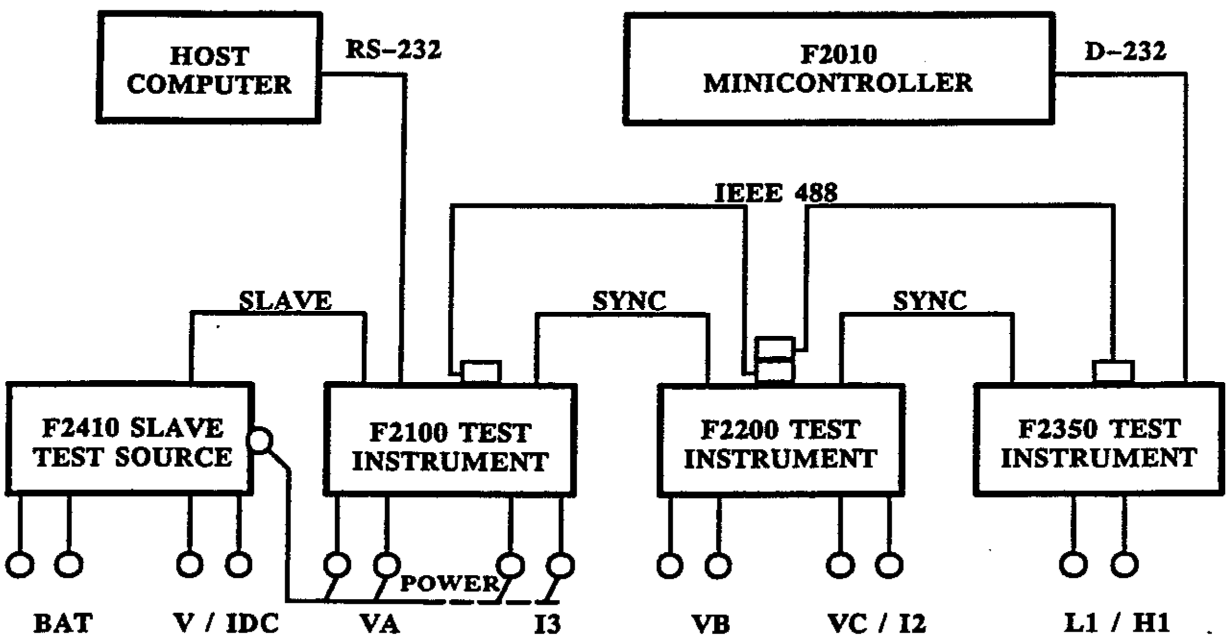


Figure 1-9. Universal 5-Source F2000 System Provides 2 V & 3 I or 3 V & 2 I for 3ϕ Testing, Minicontroller for Variable Frequency and Dynamic Testing, Host Computerfor Automated ProTesT Testing. Use of Slave Source Provides DC Voltage or Current (With the Loss of Equivalant AC Source) and Battery Simulator.

That instrument relays all messages to and from all other Test Instruments in a networked system over the IEEE-488 Bus.

REMOTE CONTROL

Any single Test Instrument (and its Slave) or networked system can be controlled remotely by an F2010 Minicontroller or by a Host Computer. Remote control is effected by the controlling device transmitting command messages to, and receiving status/data messages from, the unit it is connected to. In a networked system this unit rebroadcasts all messages it receives to the other units, and retransmits any messages from the other units to the controlling device.

Commands contain values and data that replace the information from the manual controls, or requests for values and status data (which appears in the indicators and displays) to be returned. The information from the unit or system is interpreted by the controlling device according to its internal program, and used to compose the commands. The internal program in the Minicontroller is fixed in its firmware. In the Host Computer it is either ProTesT or a special application program.

The unit or system can only be placed in the Remote Mode by the controlling device. When in Remote Mode under ProTesT all Test Instrument ON/OFF controls are changed to Abort switches. Pressing any one aborts all operations, turns all sources off, and places the unit or system back in Manual Mode.

F2010 Minicontroller

The Minicontroller is a hand-held microcomputer-based remote controller that acts as an extension of the controls for the Test Instrument it is connected to, and expands the unit's (or system's) frequency range and testing capabilities. The Minicontroller performs a number of actions. These include:

- Switching the unit/system to Remote and back to Manual.
- Turning all enabled sources on and off together.
- Changing the value of a selected source's chosen parameter.
- Changing the value of 2 or 3 similar sources together. Requires the F2825 Multiple Sources option.
- Changing a source's, unit's or system's frequency between 25.00 and 99.99 Hz in 0.01 Hz increments, and between100.0 and 600.0 Hz in 0.1 Hz increments.
- Setting two values for a selected source's chosen parameter, and switching between them instantaneously. The timer is started at the same time, and stopped when the relay trips.
- Setting a rate of change, and ramping between the two values at this rate. When ramping frequency, the timer may be started when the ramp reaches the second or selected intermediate value, and stopped when the relay trips. Requires the F2820 Δ Value/Δ Time option.

Host Computer

A 'host' computer is that computer in a multiple-computer network that controls communication over the network. The definition of an F2000 Host Computer is more substantial. To accomplish its communications control function, an F2000 Host Computer must have a standard RS-232C Serial Communications Port and use an interrupt-driven Communications Driver that can operate the port at 9600(†) baud in full duplex using 8-bit words with one stop bit and no parity.

Any digital computer capable of being an F2000 Host Computer can be used to control one or more F2000 Test Instruments (and Slave Sources). Control is accomplished by transmitting and receiving messages over an RS-232C Cable to a Test Instrument's RS-232C Port. That instrument relays all messages to and from all other Test Instruments in a networked system over the IEEE-488 Bus.

(†) *The baud rate of F2000 Instruments is selectable via DIP switches. See DobleCoL manual for details.*

All messages must be in DobleCoL, the Doble command language and communications protocol. If the Host Computer is running ProTesT III, ProTesT performs all message compilation and interpretation in DobleCoL automatically. If the Host Computer is running some other custom control program, that program must use DobleCoL to compose and interpret all its control and information messages.

ProTesT

The ProTesT III Software System is an integrated collection of proprietary programs for creating, running, documenting, and storing a library of automatic protective relay tests. It uses various ProTesTPLANs that contain generic test procedures, called 'macros', which are easily configured for specific relays. Each ProTesTPLAN contains all the different macros needed to exercise and test all parts of every type of relay in a specific IEEE family or group or related families. ProTesT III is supported for the Compaq and IBM Personal Computers. Refer to the ProTesT III System Manual for information about ProTesT, and the various ProTesTPLAN Reference Manuals for information about their test macros. (Requires F2910 ProTesT starter kit option).

DobleCoL

DobleCoL is the control language and communications protocol used by the F2000 family to control their operations and communicate control and status data between Test Instruments, a Minicontroller, and/or a Host Computer. It is an integral part of the F2000 firmware in every Test Instrument's microcomputer.

DobleCoL must be used by any program running in the Host Computer to communicate with an F2000 Test Instrument or networked system. See the F2000 DobleCoL Manual for a complete description of how DobleCoL operates, its protocol, structure, commands, and messages.

SECTION II
OPERATING CONTROLS & INDICATORS

*

The F2100, F2200, F2500, and F2350 Test Instruments can be operated either manually or remotely. Local manual control is provided by front panel controls and indicators. These are divided into three sections:

1. System controls and indicators
2. Source controls and indicators
3. Timer controls and indicators

The controls provide all the information needed to direct all operations, the indicators always show the state of the instrument and its source(s) and display the present value of all source parameters.

Manual operation can be enhanced by the optional F2010 Minicontroller, which extends the front panel controls. Remote operation is effected by a Host Computer, which sends values, commands, and requests for value and status data to the instrument, and receives error messages and requested data from the instrument.

This section describes the controls and indicators of all Test Instruments and the Minicontroller. It also describes the configuration messages that an instrument can display to indicate its state, any attached Slaves, and all installed options.

Initiation

On turnon the Test Instrument displays "Pon" while its microprocessor checks all its circuits, memory, the high–speed Doble Bus, and the controls and indicators. If everything is normal it warms up (displaying "WM") and then initializes all its controls, setting them as described below:

- Amplitudes and Phase Angles are set to zero.
- Ranges are set at their lowest setting; V = 75 V, I = 3.25 A (F2100/F2200/F2500), L/H = 5 A (F2350).
- Frequency is set to the base frequency (50 or 60 Hz) and XTAL (crystal controlled).
- On/Off controls are off.
- RAMP/SET Mode is SET.
- ZERO X System Turnon Mode is SOURCE.
- System is under local control (REMOTE is off).
- For a single system, MASTER/SLAVE mode is set to MASTER. If two or more units are connected together, the first unit powered up will be the Controller–in–Charge (CC) and MASTER, making all others SLAVES.

All manual controls and functional indicators are on the front control panel, except for the POWER switch, which is located behind the side door with the interface connectors. There are a pair of output terminals (binding posts) for each source, and a pair of input terminals for the timer. The F2350 also has a pair of high current sockets in parallel with its 20–ampere output terminals.

The instrument's actual state is always shown by its indicators, regardless of the type of control — front panel, Minicontroller, or Host Computer.

The controls are laid out logically with each source's controls and indicators in a horizontal line. Most system controls and indicators are along the bottom of the panel. The timer's controls and indicators are on the right.

SYSTEM CONTROLS & INDICATORS

The system controls and indicators determine those parameters that apply to every source in or controlled by the Test Instrument and all other sources in a multiunit system. They are located primarily below the source controls. See Figure 2-1 below.

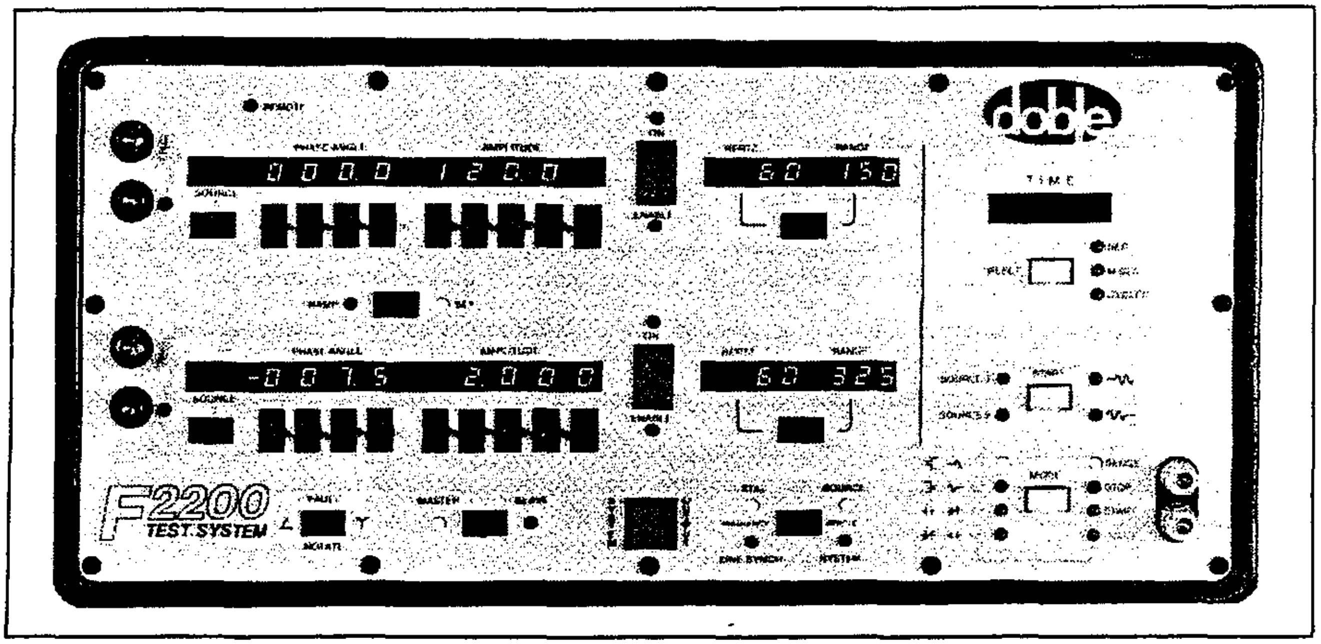


Figure 2-1. F2000 System Controls & Indicators.

REMOTE — Yellow LED indicator in upper left corner lights when the instrument is controlled by a Host Computer or a Minicontroller.

> NOTE: When a Test Instrument (and any Slave) is under remote control by a Host Computer running ProTesT, all ON/OFF switches function as interrupts: pressing any switch will abort the test in process.

RAMP/SET — Selects and displays the instrument's Amplitude and Phase Angle control modes.

SET: Pressing right enables all parameter switches to increase or decrease their own digit's value one unit at a time.

RAMP: Pressing left enables any parameter's switches to increment or decrement the present value one least significant digit at a time, at a rate depending on which switch is pressed: See Phase and Amplitude for ramp rates.

> NOTE: In RAMP/TIME Mode, AutoSensE stops the timer and turns all enabled sources off, freezing their values, when an external signal is sensed. In RAMP/SENSE the sources are left on (timer is not running in SENSE).

SYSTEM OUTPUT — Indicating pushbutton provides simultaneous on/off control for all enabled sources. When dark (off), pressing lights it (and any others in a multiunit system) and turns all enabled sources ON according to their ZERO X Turnon Mode. Any other source will then turn ON similarly when enabled.

> NOTE: System output has no control over a source turned on or off by its own ON/OFF switch.

When off, each SYSTEM OUTPUT flashes if any source has been turned on by its ON/off switch, and will not turn it (them) off.

ZERO X/FREQ — Dual-action paddle switch (active only on System MASTER Instruments) and four indicators.

ZERO X — Pressing right selects and indicates the instrument's Turnon Mode.

SYSTEM: All amplitude changes (turnon, update, and turnoff) occur simultaneously, regardless of the relative phase angles of the sources.

SOURCE: Each source changes at its first zero crossing with or after the system reference, REF 0. If set at zero degrees the change occurs at REF 0.

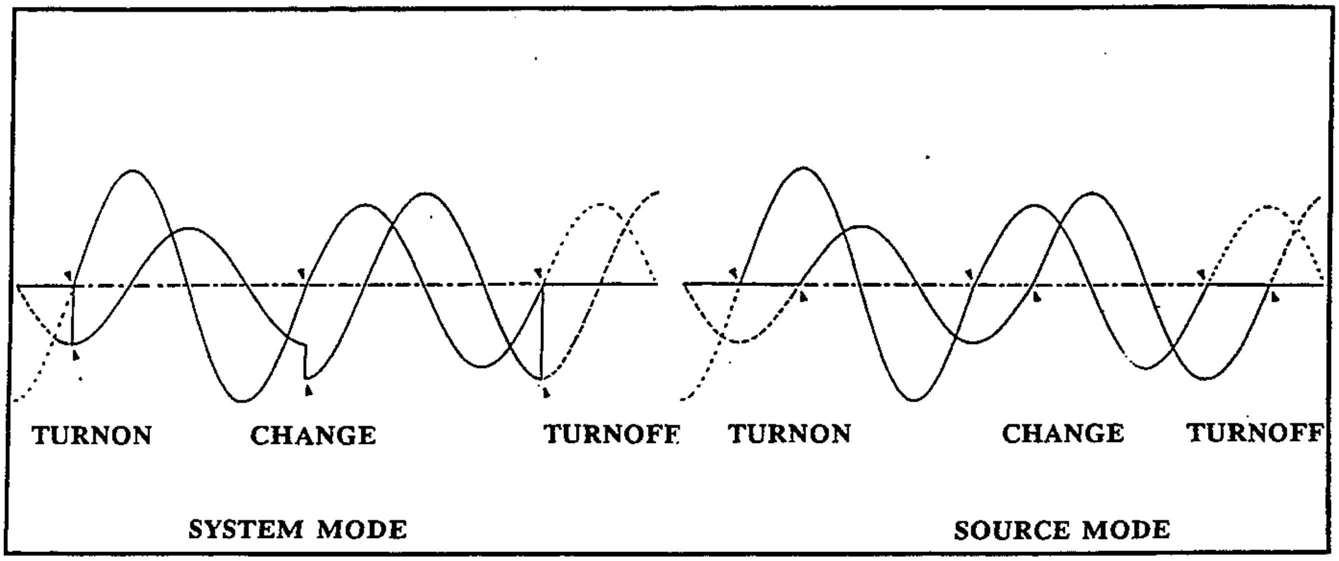


FIGURE 2-2. ZERO X CONTROL OPERATION.

FREQUENCY — Pressing left selects and indicates the system's synchronization source.

XTAL: Internal crystal-controlled frequency generator.

LINE SYNCH: Frequency generator synchronized to the power line. Tracks line frequency shifts up to ±1 Hz of base frequency (50 or 60 Hz).

MASTER/SLAVE — Only one Test Instrument in a multiunit system can be the System MASTER, which provides the frequency and timing signals for all other Test Instruments (SLAVES). Pressing left makes that Instrument the System MASTER. Pressing right displays the Instrument's configuration (it does not change the unit to SLAVE). See CONFIGURATION DISPLAY & MESSAGES, page 2-7.

FAULT ROTATE (option) — Changes the parameters of a simulated 3-phase fault to effectively rotate the fault(s) 120° counterclockwise into the next phase(s). Pressing right changes Y configurations (3 voltages and 1 or 3 currents) and pressing left changes Open Δ configurations (2 voltages and 1 current). Avoids having to change voltage (and 3-phase current) connections. Only single current connections must be changed. See examples in Tables 2-1 and 2-2.

Source designations must be consistent with the convention being used, i.e., VA/VB/VC goes with I1/I2/I3, VR/VS/VT with IR/IS/IT, VR/VY/VB with IR/IY/IB. Voltage sources must be on the same range, and multiple current sources must be the same type (H, L, or I) and on the same range. Paralleled current sources are considered a single source (IP).

NOTE: All voltage and current sources must be set to the same range.

TABLE 2-1. WYE CONFIGURATION FAULT ROTATE OPERATION.

Source	Initial Values	First Rotation	Second Rotation
VA	10.0 V @ 10°	69.3 V @ 0°	69.3 V @ 0°
I1	15.0 A @ -70°	5.0 A @ 0°	5.0 A @ 0°
VB	69.3 V @ -120°	10.0 V @ -110°	69.3 V @ -120°
I2	5.0 A @ -120°	15.0 A @ -190°	5.0 A @ -120°
VC	69.3 V @ -240°	69.3 V @ -240°	10.0 V @ -230°
I3	5.0 A @ -240°	5.0 A @ -240°	15.0 A @ -310°

TABLE 2-2. OPEN Δ CONFIGURATION FAULT ROTATE OPERATION.

Source	Initial Values	First Rotation	Second Rotation
VA	30.0 V @ 0°	105.0 V @ 0°	105.0 V @ 0°
VB	105.0 V @ 81.8°	30.0 V @ 81.8°	105.0 V @ 16.4°
I1	*If* A @ -75°	*If* A @ -173°	*If* A @ 23.2°

SOURCE CONTROLS, INDICATORS, & DISPLAYS

HIGH VOLTAGE ALARM — Red LED below the lightning symbol blinks when >20 volts is present.

SOURCE — Dual-action paddle switch and 2-digit display selects type and designation.

Type (left deflection & digit):

V = Voltage (F2100, F2200, and F2500)
I = Current (F2100, F2200, and F2500)
IP = Parallel Current Mode (F2100, F2200, and F2500)
L/H = High Power Current Mode (F2300/F2300A/F2350);
DI = Slave DC Current (F2410 via F2100, F2200, F2500, F2350)
DV = Slave DC Voltage (F2410 via F2100, F2200, F2500).

Designation (right deflection & digit):

Standard: V: A, B, C; I/L/H: 1, 2, 3;
ProTesT & Extended options: R, S, T; R, Y, B;
Multiple sources option (with minicontroller) VM, IM, L/HM.

NOTE: Current sources must be off to be switched into or out of the Parallel Mode. Switching reinitializes paralleled sources.

PHASE ANGLE — 4 decimal digits and dual-action paddle switches display and specify the phase angle.

Display:

000.0 to ±359.9°. + = leading & – = lagging.

NOTE: In Parallel Mode the System MASTER shows the phase angle of all parallel I sources, and the parallel SLAVE sources show PAr.

NOTE: The phase angle display of SRC1 of the MASTER is blanked when SRC1 and SRC2 of the MASTER are running at different frequencies, and whenever FREQ and SRC1 or SRC2 is selected on Minicontrollers, since there is no fixed phase relationship between the sources in this case.

Switches:

SET Mode: increments (up) and decrements (down) the digit immediately above it.
RAMP Mode: increments (up) and decrements (down) the least significant digit at a rate depending on location:
tenths = 0.1°/sec,
units = 0.2/°sec,
tens = 0.5/°sec,
hundreds = 36°/sec.

NOTE: In Parallel Mode the System MASTER controls the phase angle of all parallel current sources.

AMPLITUDE — 5 decimal digits and dual–action paddle switches display and specify the source's rms amplitude. Maximum value and decimal point depend on the range. Only 4 digits are active at a time (except in Parallel Mode).

Display:

Voltage: 00.00 to 300.0 V.
Current: 0.000 to 26.00 A (F2100/F2200/F2500), or to 160.0 A (F2300/F2300A/F2350).

NOTE: In Parallel Mode the System MASTER shows the total amplitude of all paralleled I sources and the SLAVE sources show *ALLEL*.

Switches:

SET Mode: increments (up) and decrements (down) the digit above each switch.
RAMP Mode: increments (up) and decrements (down) the least significant digit at a rate depending on location:
right = 1 LSD/sec,
right center = 2 LSD/sec,
center = 5 LSD/sec,
left center = 10 LSD/sec,
leftmost 1/10 range/sec, approximately (dependent upon range).

NOTE: In Parallel Mode the System MASTER controls the total amplitude of all paralleled I sources.

ON/ENABLE — Dual–action paddle switch and indicators display and control the source's on/off state.

ON: turns source on (red LED lighted) or off (LED dark)directly. Overrides ENABLE.
ENABLE: enables (green LED on) or dis–enables (LED dark) the SYSTEM OUTPUT pushbutton control of the source (and all other enabled sources).

NOTE: In Parallel Mode the System MASTER enables or disables and turns on or off all paralleled I sources.

HERTZ — 4 decimal digits and dual–action paddle switch display and control the source's frequency.

Display:

XTAL on: 50/60 Hz on startup, cycled through 500/600 Hz(tenth harmonic) by paddle switch.
LINE SYNC on: FL on startup, cycled through FL10 (tenth harmonic) by paddle switch.

Other Modes:

REMOTE on (Minicontroller/Host Computer options): 25.00 to 99.99 and 100.0 to 600.0Hz.
F3 on: F3 (50 or 60 Hz from the F3 3ϕ Test System).
Paddle Switch (unmarked): Changes source's frequency to the next higher harmonic when pressed to left. Returns to fundamental from tenth harmonic. Disabled when source is enabled or on.

RANGE — 4 decimal digits and paddle switch display and select the source's range.

Display:
V source: 75.0, 150.0, 300.0 V.
I source: 3.25, 13.0, 26.0 A. (F2500 SRC1 = 2.25, 9.0, 18.0)
F2300A L/H source: 5.00, 15.0, 30.0, 45.0, 70.0, and 160 A.
F2300/F2350 L/H source: 5.000, 10.00, 15.00, 20.00, 25.00,30.00, 40.00, 50.00, 80.0, and 160.0 A.
Aut: AutoRange mode (automatically selects lowest possible range).

Paddle Switch (unmarked)*:* Changes source's range to next higher value when pressed to the right. Goes to *Aut* then back to lowest range. Disabled when the source is enabled or on.

TIMER CONTROLS, INDICATORS, & DISPLAY

Every F2000 series instrument has an integrated Digital Timer for measuring and displaying the time between events. It counts 10-microsecond intervals, and displays the count in milliseconds, seconds, or cycles. It also has a Sense Mode for notifying the operator when an untimed event occurs. The Timer's controls, indicators, and display are on the right side.

The CYCLES mode of the timer is based on the frequency (50 or 60 Hz) selected by the dip switch on the timing generation board and counts on this basis no matter at what frequency the source is running.

TIME — 5-digit display shows the elapsed time or SENSE.

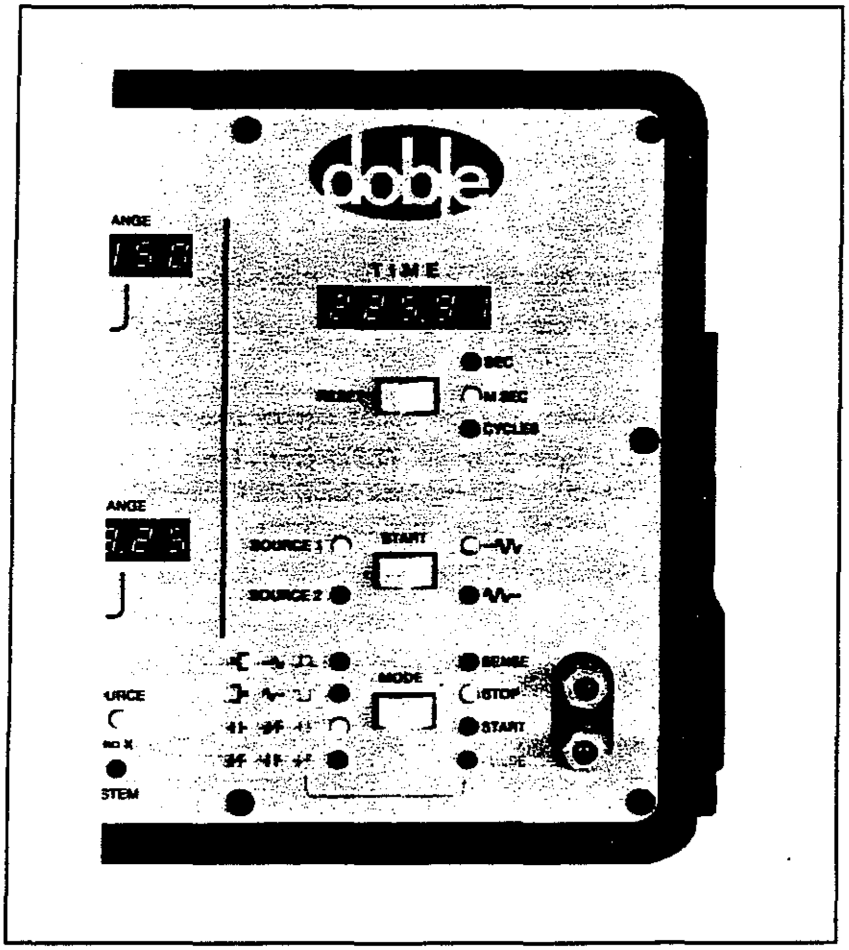


Figure 2-3. F2000 Timer.

RESET — Dual-action paddle switch either resets the timer or selects and displays its units. Pressing left clears and resets the timer.

Pressing right selects the range and display units cyclicly:

SEC: 000.00–999.99 seconds, in 10 ms increments. Automatically selected by AutoRange if MSEC range is exceeded.

MSEC: 000.00–999.99 milliseconds, in 10 μs increments.

CYCLES: 000.00–999.99 cycles at 50/60 Hz (166.7/200 μs increments). Does not overrange to SEC but correct result can be read after CYCLES overrange if SEC range is then selected.

START — Dual-action paddle switch and indicators select and display either the source or its off–on or on–off transition for starting the timer. (The single-source F2350 only selects the transition). This control is active only in the STOP mode.

SOURCE:

SOURCE 1 } START TIMER ON SELECTED TRANSITION OF THIS SOURCE.
SOURCE 2 }

TRANSITION:

 (OFF-ON) START TIMER ON THIS TRANSITION OF THE SELECTED SOURCE.

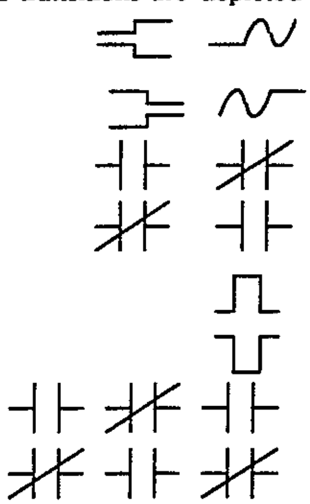
 (ON-OFF) START TIMER ON THIS TRANSITION OF THE SELECTED SOURCE.

MODE — Dual-action paddle switch cyclicly selects and displays either the four Timer modes or the type and transition of the sensed signal.

Pressing right selects and displays the mode:

SENSE (green LED): Sounds beeper and displays SENSE when sense conditions occur.
STOP (red LED): Sounds beeper, turns SYSTEM OUTPUT off, and stops Timer when sense conditions occur.
START (amber LED): Starts Timer when sense conditions occur. (Used only with F2845 option)
PULSE (amber LED): Starts and stops the Timer to measure the width of a pulse.

Pressing MODE to the left cyclicly selects the type of external signal to be sensed and its action transition. The types and transitions are depicted graphically.



= voltage off→on, (1–300 V dc or ac);
= voltage on→off, (1–300 V dc or ac);
= dry contacts, open→closed;
= dry contacts, closed→open;
= pulse volts off→on→off;
= pulse volts on→off→on;
= pulsed contacts open→close→open ;
= pulsed contacts close→open→close.

SENSE/TIME TERMINALS — Accept an external signal from dry contacts or a voltage source. In voltage mode the input impedance is 100 KΩ. Signals from 1 to 300 volts, ac or dc, can be sensed. In contact mode, the terminals are active, supplying 30 V/90 mA dc to sense the contacts' status. If a voltage of 1 volt or more is present, a contact mode cannot be selected. The upper terminal is fused to protect the circuit.

CONFIGURATION DISPLAY & MESSAGES

Pressing and holding the MASTER/SLAVE switch to the right causes configuration messages to appear in the source and timer displays. These define the unit and all its options.

The configuration messages specify the unit's model number, its software revision number, the base frequency (selected by a switch on the Timing Generator card), any installed options, any attached Slave units, and the Doble bus network address. Each message is shown in a specific display area. See Figure 2–4 and Table 2–1.

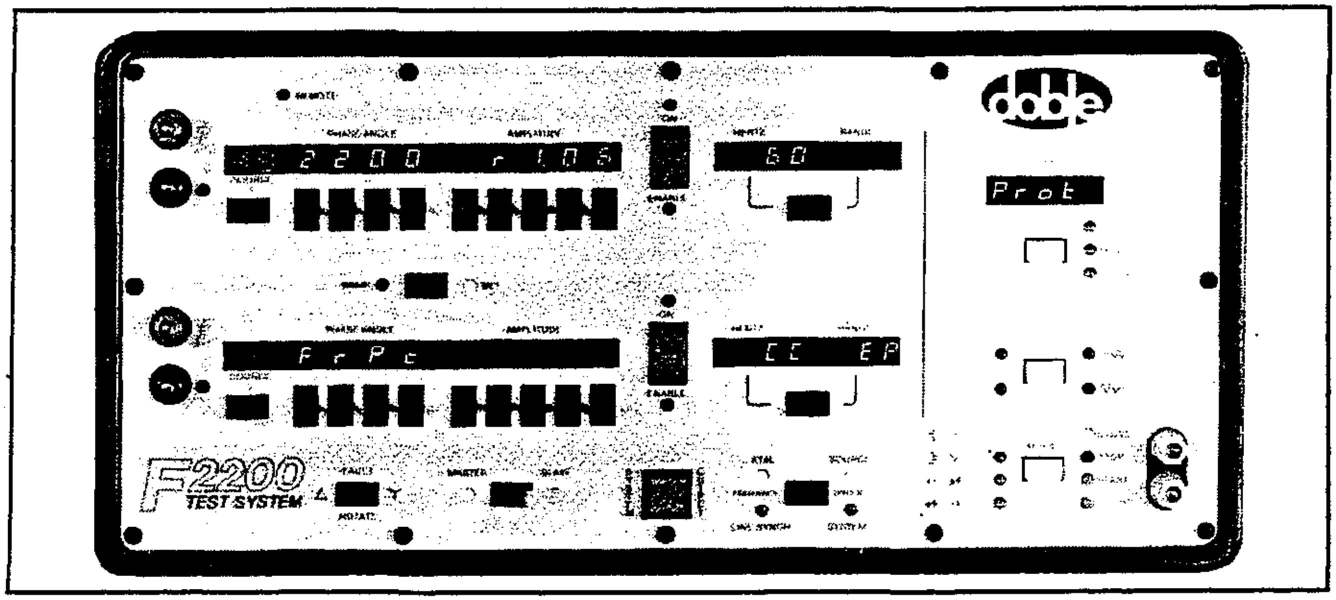


Figure 2–4. Typical Unit Configuration Messages.

TABLE 2–1. CONFIGURATION MESSAGES.

#	DISPLAY	MESSAGE	MEANING
1.	SOURCE 1	MS	F2825 Multiple Sources option
2.	S1 PHASE ANGLE	nnnn	Model Number (2100, 2200, 2350)
3.	S1 AMPLITUDE	Em.nn	Software Revision Number
4.	S1 HERTZ left digit	H	High Power Current Slave (F2300A) U=F2380 T=F2375
5.	S1 HERTZ right 2 digits	50/60	Base Frequency
6.	S1 RANGE left digit	t	TWG Board Installed (F2860)
7.	S1 RANGE middle digit	2	Second Slave Board Installed (not in version 2.09) (F2860)
8.	SOURCE 2	dV	F2820 Δ Value/Δ Time Option
9.	S2 Phase angle left	Fr	Fault Rotate Option (F2810)
10.	S2 Phase angle right	Pc	Precision Frequency Option (F2850)
11.	S1 Range right digit	S	Satellite Board Installed (F2870)
12.	S2 AMPLITUDE right 3.	PH1/2/4	4 = F2920 Precision Autosynchronizer Advance Time Measurement 1 = F2835 Phase Interface 2 = F2845 Dual Phase Interface
13.	S2 HERTZ left	dc	F2410 Slave DC Source
14.	S2 HERTZ right	CC/nn	Network Address
15.	S2 RANGE	US/EP	US/EXtended Source Designations
16.	TIME	Prot	F2910 ProTesT Starter Kit

The first unit turned on in a multiunit system is the Controller-in-Charge (CC), which directs communications over the IEEE-488 Bus. The SOURCE 2 FREQ display shows either CC or a 2-digit number (the network bus address) to identify the unit in a multiunit system.

NOTE: The base frequency can differ from the system frequency, which is set by the MASTER.

MINICONTROLLER CONTROLS & INDICATORS – See Minicontroller Manual for full description.

The Minicontroller has 7 pushbuttons and a rotating knob. These controls and their functions are described here. See Section III for their operation, and the Minicontroller Manual for using the Minicontroller.

POWER — Turns the Minicontroller ON and loads the sources' amplitudes, phase angles, and frequencies into both Set Value Registers, A and B.

Pressing POWER again turns the Minicontroller off.

SYSTEM OUTPUT — Pressing SYSTEM OUTPUT turns all enabled sources ON and lights the indicator, or turns them off

SRC#1/SRC#2/BOTH — Selects the source whose parameter is to be changed. BOTH is only available and is automatically preselected when FREQ is selected.

AMPL/PHASE/FREQ — Chooses the selected source's parameter that is to be changed. FREQ controls SRC #1, 2, or BOTH; AMPL/ PHASE only SRC #1 or SRC #2

Value Knob — Changes the chosen parameter when rotated. Clockwise rotation increases the amplitude and frequency, and decreases the phase angle in a lagging direction, and vice versa. The rate depends on the speed of rotation and the state of the RESOLUTION control. The value is shown in the source's display at all times.

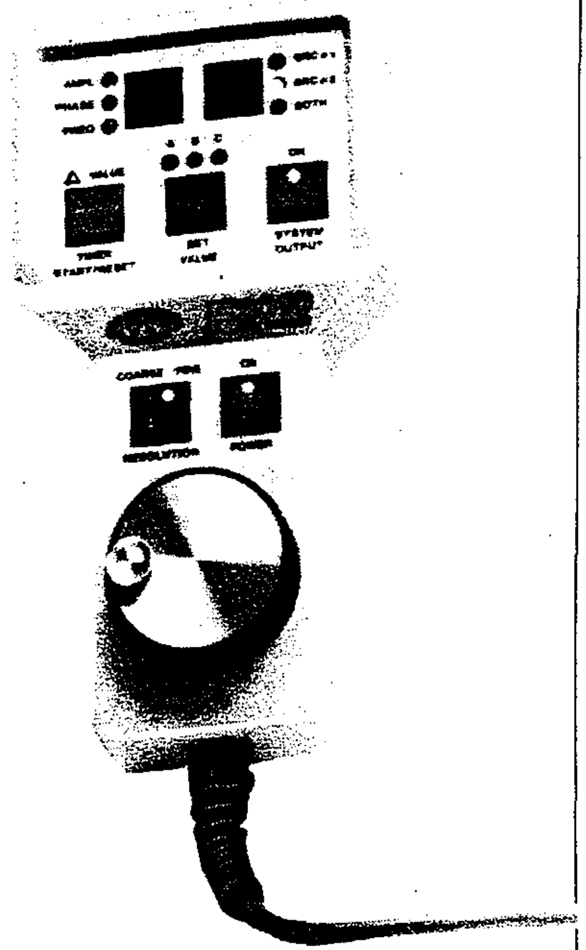


Figure 2–5. F2010 Minicontroller.

RESOLUTION — Switches between FINE and COARSE when pressed. FINE causes the chosen parameter's value to change 16 least significant digits (LSD's) for each full rotation of the knob. COARSE causes the value to change at least 8 times as much, or 128 LSD's per revolution. COARSE makes value knob velocity sensitive; turning the knob faster causes greater changes.

SET VALUE — Saves the parameter values of both sources (amplitude, phase angle, and frequency) in two Set Value Registers, A and B; and if the F2820 Δ Value/Δ Time option is installed, a rate of change in Rate Register C.

Δ VALUE — Performs a Dynamic (Δ VALUE) Test when pressed, changing the selected source's chosen parameter from its present value to the value in the alternate Set Value Register and starting the timer. The change occurs instantly, at a zero crossing, or at the rate in C if the F2820 Δ Value/Δ Time option is installed.

SECTION III
SET-UP & OPERATION

*

The F2000 family can be operated manually using the Test Instruments' controls and indicators (enhanced by the optional F2010 Minicontroller), or remotely by a Host Computer.

This section describes how to:

A. set up a Test Instrument,

B. attach a Slave Source,

C. attach an F2010 Minicontroller,

D. add additional units to form a multiunit system,

E. turn an Instrument ON and set its initial configuration,

F. set the base frequency,

G. assign source designations,

H. change the source parameters, and

I. configure the timer.

It also tells how to:

1. use Parallel Sources,
2. use Fault Rotate, and
3. use the Minicontroller.

See Section V, CALIBRATION VERIFICATION to check for proper operation after turnon.

SETUP

1. Place the Instrument close to the relay to be tested, either stacked vertically or horizontally on the floor.
2. Pull the front cover off and place it to one side.
3. Open the sliding access door on the right side by pushing it in and backwards until it stops. This provides access to the on/off switch, ac power cord socket, timer/sense fuse, and external interface connectors.
4. Check that the switch labeled POWER ON is off (down); then plug the power cord into the socket labeled A.C. POWER and into a 120 V 60 Hz ac mains (or 240 V 50 Hz if the unit is so labeled).

   NOTE: The ac mains must be capable of supplying 10 A for each F2100, F2200, or F2500; 20 A for each F2300, F2300A or F2350; 5A for each F2410. Ensure earth ground precautions are observed!

5. If an F2010 Minicontroller is to be used, plug its cable into the D232 connector of the Test Instrument it is to control.

   NOTE: On PHASE or MAGNITUDE Minicontroller controls only the Test Instrument it is attached to, unless all the Test Instruments in a multiunit system have the F2825 Multiple Sources option installed. On FREQUENCY all SLAVES follow sources 2 of MASTER.

6. If another Test Instrument is to be used, repeat steps 1 through 4, then connect them together as described under MULTI-UNIT SYSTEMS.(3-5)
7. If an F2000 Slave source is to be used repeat steps 1 through 4, then connect them as described in Slave Sources (3-2).
8. Go to "STARTUP" Section.

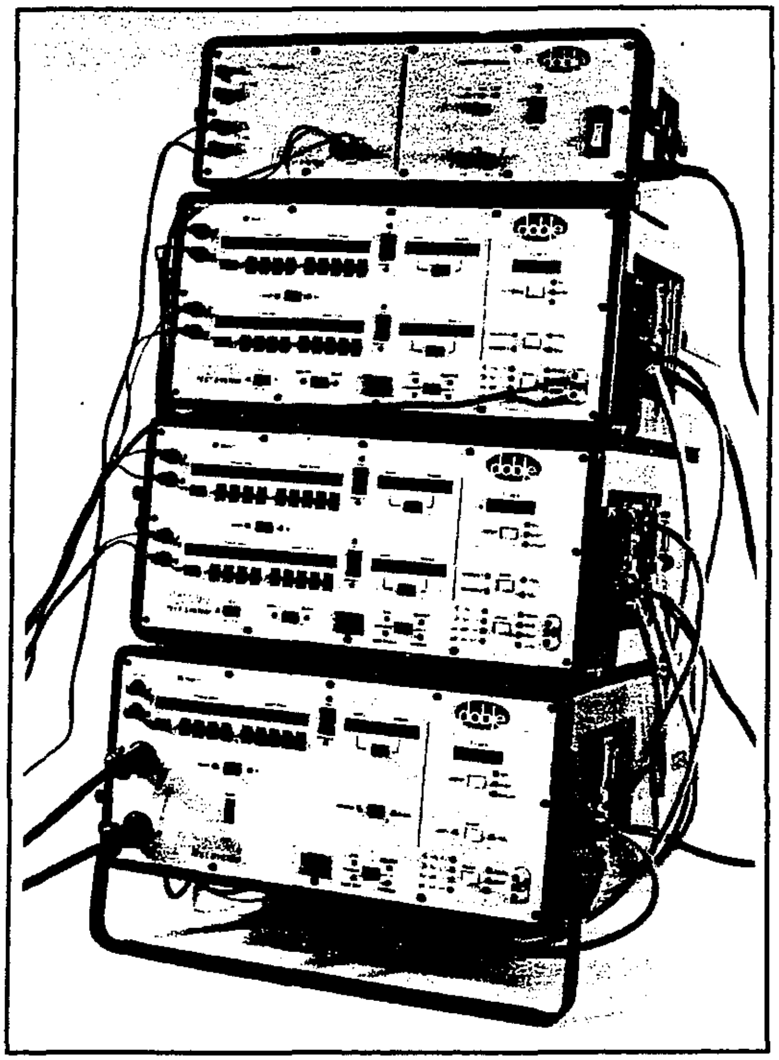


Figure 3-1. F2000 Instruments Stacked in a Multiunit System.

■■■■■■■■■■ CAUTION ■■■■■■■■■■
Never stack more than three F2000 instruments (and an F2410 Slave DC Source) together.

■■■■■■■■■■ CAUTION ■■■■■■■■■■

Do not stack units directly above each other. Set each unit back about one inch to engage the interlocks.

■■■■■■■■■■ CAUTION ■■■■■■■■■■

Be sure the safety ground (green wire) of every Test Instrument and Slave Unit is connected to the same ground at the ac mains outlets.

If any unit is connected to a different ground, large ground loops can exist and the units may not work.

SLAVE SOURCES

F2000 Slave Sources provide extended output capability for an F2000 System. F2000 Slave Sources are controlled by the microcomputer in F2000 Instruments, via the AC and DC Slave Interfaces.

For an F2000 Slave to operate, it must be interconnected with an F2000 Master via the appropriate interface cable. For the F2300 Slave, the interconnecting cable carries low-level analog ac signals from the F2000 Master to the F2300 where the signals are amplified. For the F2410 DC Slave, there are two cables. One cable transfers control information; the other cable carries a high-level ac signal from the F2000 Master to the F2410 where it is converted to either a dc voltage or dc current.

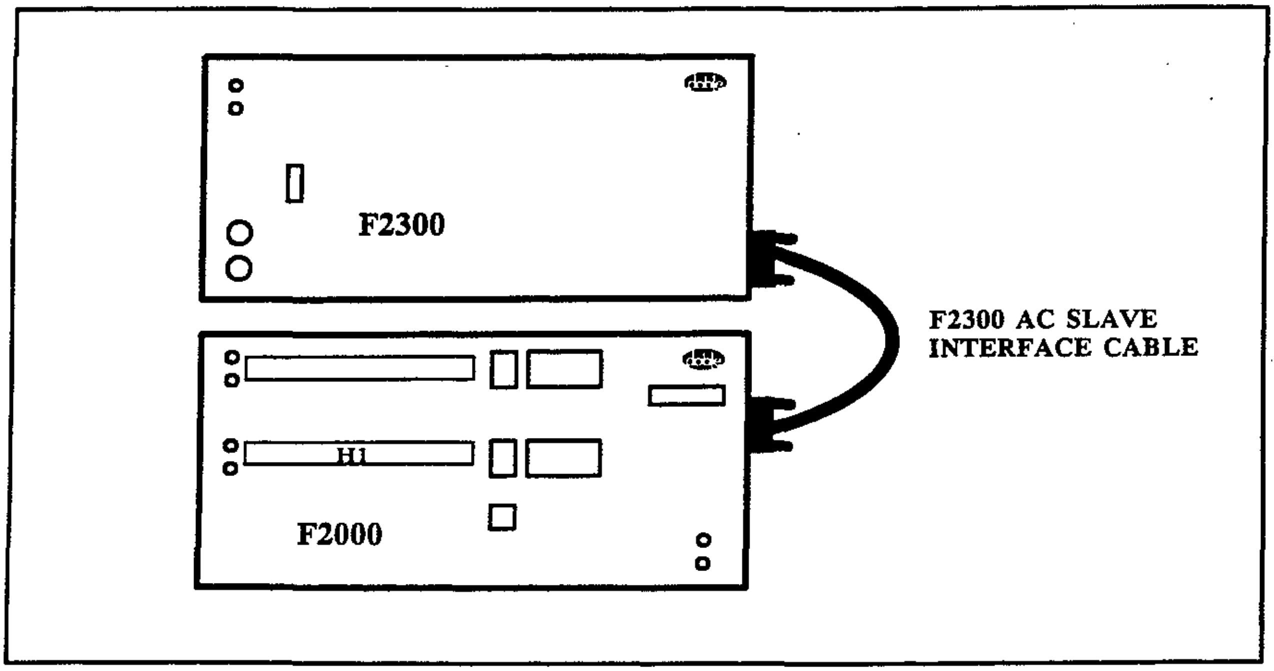
The F2410 is also used to provide station battery simulation for testing relays which require 48, 125, or 250 volts dc. The battery simulator function is not a Slave function; the F2410 produces this output directly from an independent, regulated source.

All Slave Sources may be controlled by ProTesT. In an automated test system, all functions of the F2300 or F2410 may be fully manipulated under computer control by using ProTesT II. The F2300 Slave High Power current source is controlled through the operator window of another F2000 source (F2100, F2200, F2500). When the F2300 Slave is set for control through a voltage or current source in the Master F2000 unit, that F2000 source in the Master is no longer available for use.

SLAVE SOURCES (continued)

F2300 OPERATION

To operate the F2300, the power should be ON and the 37-pin AC Slave interface cable between the F2300 and the F2000 Master Instrument should be in place and secured. The interface cable is inserted into the socket labeled "F2300" on the side panel of the F2000 Master Instrument.



F2300 Connected to F2000 Instrument (F2100, F2200, or F2500)
Figure 3.2

The F2300 Slave has two power levels designated "L" and "H". The maximum Volt-ampere output while in mode "L1, 2, or 3" is 300 VA continuous and 500 VA, 50% duty cycle while in mode "H1, 2, or 3". Select the desired mode through the source assignment window of the F2000 Master. The F2300 may be controlled via either a voltage or current source.

Select one of ten current ranges by operating the RANGE switches of the Master source or select Autorange by operating the range switch until "Aut" is displayed in the RANGE window. Select the amplitude by operating the front panel controls of the Master source in either SET or RAMP mode. The amplitude may also be set with the knob of the F2010 Minicontroller, if installed.

Connect the output of the F2300 to the relay under test using the larger interconnecting cables provided with the Instrument. For tests requiring 25 Amperes or less, the smaller binding posts and test leads can be used.

If the Master F2000 Instrument is fitted with the F2820 Δ Value/Δ Time option, the output of the F2300 may be automatically ramped through the use of the F2010 Minicontroller. To automatically ramp the amplitude, phase, or frequency of the F2300 Slave, the initial value, end value, and the ramp rate may be set and stored by the F2010. Once enabled, the F2300 is switched on using the system output switch of the F2010. The output is automatically ramped at the preset rate by pressing the "DELTA VALUE" button of the F2010.

SLAVE SOURCES (continued)

F2410 OPERATION

To operate the F2410 **DC Slave Source**, the power should be ON, and the cable between the F2410 and the F2000 (F2100, F2200, F2350, F2500) Master Instrument should be in place and secured. The cable is plugged into the socket labeled "F2410" on the side panel of the F2000 Instrument.

To use the F2410 as a dc current source, select "DI" on the source assignment switch of a current source on the Master F2000 unit. With the source designated "DI", the Phase window is blank and the Hertz window displays "dc". Observing correct polarity, connect the F2000 "DI" current *output* to the *input* of the F2410 using the interconnecting leads supplied with the F2410. When the source is designated "DI", the range is preset to 3.25 amperes and is not adjustable.(5amps with F2350)

Dc current amplitude is set by using the front panel controls of the "DI" source in either the SET or RAMP mode. The amplitude may also be set with the knob of the F2010 Minicontroller, if installed. The Current is output through the terminals labeled "IDC" on the F2410.

To use the F2410 as a dc voltage source, select "DV" with the source assignment switch on a voltage source of the Master F2000 unit. With the source designated "DV", the Phase window is blank and the Hertz window displays "dc". Observing correct polarity, connect the *output* of the source designated "DV" to the *input* of the F2410 using the interconnecting leads. Select the range by operating the front panel controls of the source designated "DV". Note: DV mode not possible with F2350.

With a voltage source of the F2000 Master Instrument assigned as "DV", the DC Voltage amplitude is selected by using the front panel controls of the Master in either the SET or RAMP mode. The amplitude may also be set with the F2010 Minicontroller, if installed. The Voltage is output through the terminals labeled "VDC" on the F2410.

The output of the F2410 in either voltage or current mode may be controlled manually ONLY by pressing the ON/ENABLE of the Master source controlling the F2410 switch to the ON position. If the Master F2000 Instrument is fitted with the F2820 Δ Value/Δ Time option, the output of the F2410 may be automatically ramped using the F2010 Minicontroller.

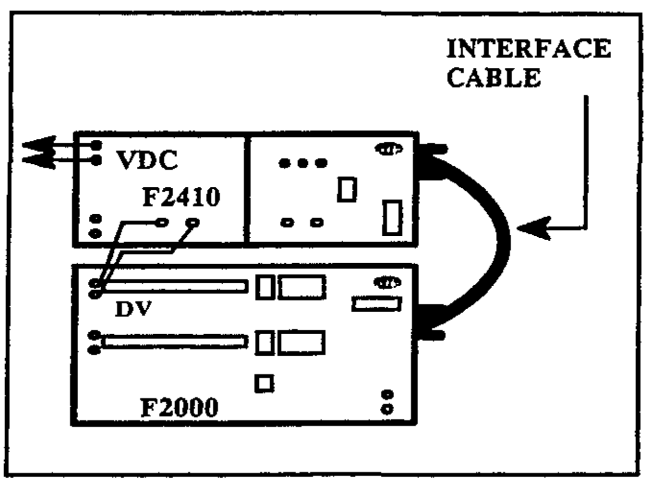


Figure 3.3
F2410 Connected for DC Voltage Output

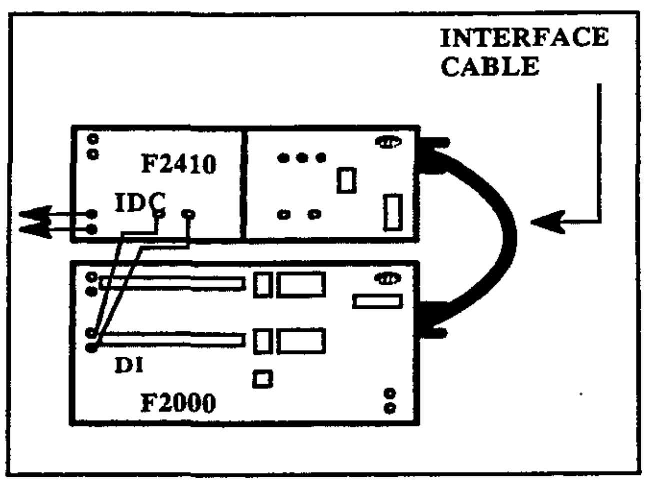


Figure 3.4
F2410 Connected for DC Current Output

SLAVE SOURCES (continued)

To automatically ramp the output of the F2410 DC Slave source, the initial value, end value, and the ramp rate may be set by the F2010. The F2410 is switched ON using the ON/ENABLE switch of the F2000 Master source at the initial amplitude of the ramp. The amplitude is then automatically ramped at the preset rate by pressing the "DELTA VALUE" button of the Minicontroller.

Pressing the "SYSTEM OUTPUT" button of the F2000 Master Instrument or the F2010 Minicontroller has no effect on the output of the F2410.

The timer of the Master Instrument is available for use with Source DV, but not with DI. The user may Start or Stop the timer upon turn-on or turn-off of Source DV. The timer may be stopped with any of the available SENSE state changes of the Master Instrument.

To operate the F2410 **Battery Simulator**, connect its output to the relay or device under test where the station battery would normally be connected (observe polarity).

Select the desired output voltage by moving the range selector switch either left or right until the corresponding LED range indicator is lit.

Battery Simulator output is controlled by the red OFF/ON rocker switch. Press (and release) the switch to the "ON" position. The "ON" LED will light and the output LED will flash, indicating the presence of DC voltage at the output terminals.

**** IMPORTANT ****

The correct physical positioning of the F2410 is essential in maintaining uninterrupted operation of the Battery Simulator. The following are considered **acceptable** operating positions:

- Resting on its interlocking bottom feet (front panel perpendicular to the mounting surface).
- Resting on its rear rubber feet (front panel facing up).
- Any angular position between the limits specified above.

The following are considered **unacceptable** operating positions:

- Resting on either side or more than 15° from the horizontal side to side.
- Resting on its top cover.
- Positions that exceed the limits specified above.

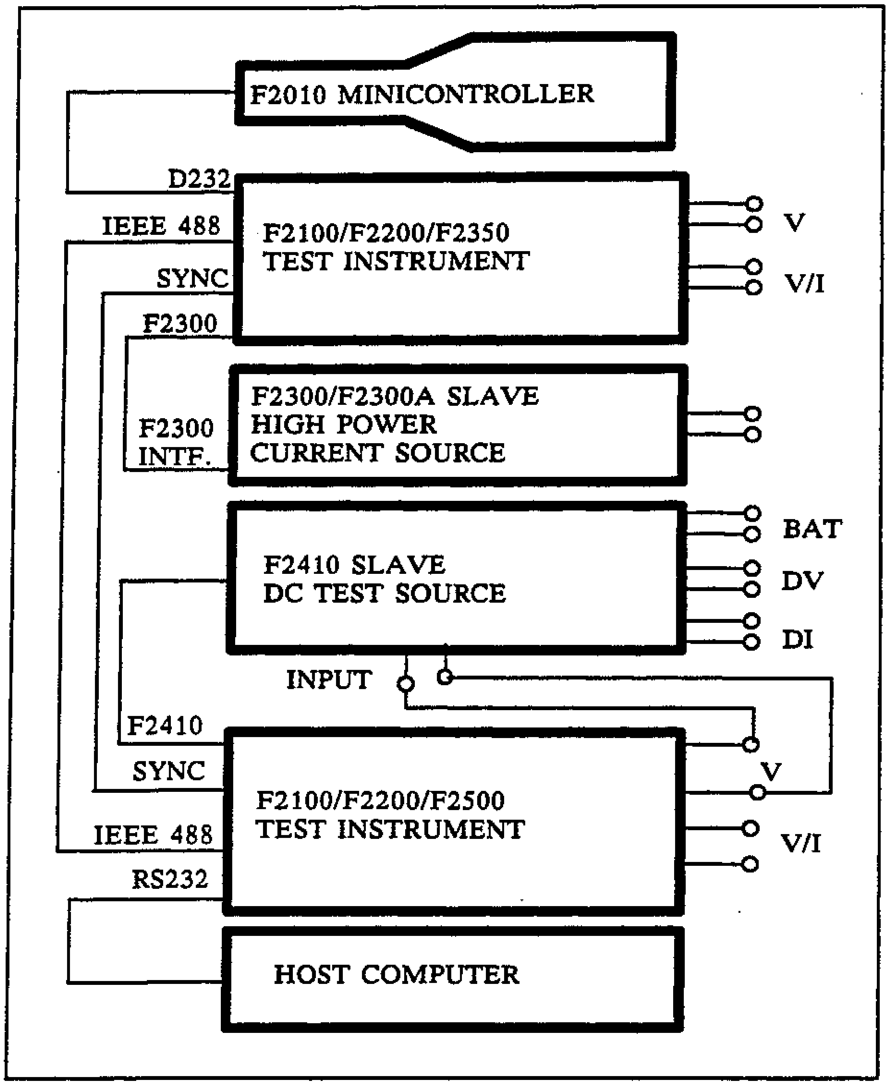
These guidelines must be followed in order to stay within the range of the mechanical compensation device, which automatically corrects the position of the mercury output relay as the Instrument is moved throughout its position limits. Attempts to operate the F2410 beyond these limits will cause the DV or DI source designators to display "**PE**" indicating a *position error*, and a loss of output.

MULTI-UNIT SYSTEMS

Up to six F2000 series Test Instruments (plus an equal number of Slaves), can be connected together to form a single multiunit system. The Test Instruments are connected by two types of cables:

- A SYNC Cable transmits the clock pulses and the zero reference signal (REF 0) from the System Master to all other Test Instruments to synchronize their frequency, phase angles, and operations;
- An IEEE-488 Bus transmits commands and data from one Test Instrument to all the other Test Instruments to communicate operating and status information.

NOTE: Be sure to fasten all cables into their connectors securely, using the knurled jack screws on the cable's connectors.



NOTES:

1 The F2010 must be connected to the F2000 Test Instrument it is to control, which must be the System MASTER.

2 All F2000 Test Instruments are to be connected together by a SYNC Cable and an IEEE 488 Bus.

3 An F2300/F2300A Slave must be connected to its Master's F2300 port.

4 An F2410 must be connected to its Master's F2410 port, and its INPUT terminals connected to its Master's output terminals.

5 A Host Computer can be connected to any F2000 Test Instrument's RS-232 port.

Figure 3-5. F2000 System Interconnections.

To create a multiunit system, first set up all the units as described. Then connect all the Test Instruments together using the SYNC cable and IEEE 488 cables. A 2-Instrument system uses one SYNC Cable and one IEEE-488 Bus; systems with 3 or more Test Instruments use an additional SYNC Cable and IEEE-488 Bus for each extra Instrument. SYNC connectors are wired in parallel internally. The second IEEE-488 Bus plugs into the back of the first IEEE-488 Bus.

STARTUP

Turnon

Raise the POWER ON switch to turn a Test Instrument ON. Its fan should run, its displays flash, and the TIME display show Pon for a few seconds while the self-testing diagnostics are run; then "WU" as its power supply warms up. If not connected to another Test Instrument (but may have a Slave attached), it then initializes its source(s) and becomes active. Its indicators should be in the turnon states listed below.

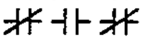
Upper Source (all Instruments):

SOURCE 1	= VA (F2100/F2200/F2500) or L1 (F2350),
PHASE ANGLE	= 000.0,
AMPLITUDE	= 00.00,
ON	= dark (off),
ENABLE	= dark (off),
HERTZ	= 60 (or 50 if set internally),
RANGE	= 75; (5A on F2350)

Lower Source (F2100/F2200 only):

SOURCE 2	= I1,
PHASE ANGLE	= 000.0,
AMPLITUDE	= 0.000,
ON	= dark (off),
ENABLE	= dark (off),
HERTZ	= 60 (or 50 if set internally),
RANGE	= 3.25;

Timer LED indicators (all units)

SEC	= dark (off),
MSEC	= dark (off),
CYCLES	= dark (off),
SOURCE 1	= dark (ignored),
SOURCE 2	= dark (ignored),
	= dark (ignored),
	= dark (ignored),
SENSE	= lighted (selected),
STOP	= dark (ignored),
START	= dark (ignored),
PULSE	= dark (off),
	= lighted (V off → on),
	= dark (off),
	= dark (off),
	= dark (off);

System LED Indicators (all units)

REMOTE	= dark (off),
RAMP	= dark (off),
SET	= lighted (on),
MASTER	= lighted (on),
SLAVE	= dark (off),
SYSTEM OUTPUT	= dark (off),
XTAL	= lighted (on),
LINE SYNCH	= dark (off),
SOURCE ZERO X	= lighted (on),
SYSTEM ZERO X	= dark (off).

If the displays and indicators are correct, the Instrument is ready to run. If not as shown, see ERROR MESSAGES (APPENDIX A).

To check on what firmware version and options are installed, press and hold the SLAVE control to the right. See Section 2–8, CONFIGURATION, DISPLAY, and MESSAGES.

Controller-in-Charge

Turn each Test Instrument in a multiunit system ON sequentially. The first unit powered up becomes the Controller-in-Charge (CC) of network communication and the System Master. As each subsequent unit is turned on it is attached to the network and assigned a network address by the Controller-in-Charge, then waits in the Pon state until all the units have powered up, when they are activated simultaneously.

> NOTE: Always turn multiple Test Instruments ON in sequence to avoid contention for position on the Bus. Simultaneous turnon from a common ac mains source can result in a Network Error due to bus contention. If this happens, follow the recovery sequence described in NETWORK ERRORS to restore normal operation.

Although the System Master can be switched to another Test Instrument (after every unit has been powered up and is running without errors), the Controller-in-Charge remains the same until the system is restarted (either by a new powerup sequence or by recovery from a Network Error).

CONFIGURATION

Once an F2000 Test Instrument (and any Slave Source) has been powered up, it must be configured before it can be used. Configuring consists of (when necessary);

A. Selecting the base frequency,
B. Assigning source designations,
C. Setting the source parameters, and
D. Configuring the timer.

Base Frequency

The base frequency in XTAL Mode is determined by a toggle switch on the TIMING GENERATOR card. To change it, remove the top half of the System Master's cover by unscrewing the two rubber feet or castors at its rear, then sliding it back. Locate the switch on the TIMING GENERATOR card (it has two SYNC connectors), and set it to 50 or 60 Hz as desired. If the Instrument is on, press the RESET pushbutton on the CPU card (it has RS232 and D232 connectors) twice to reinitialize the microcomputer. The cover can then be replaced.

If a Minicontroller or a Host Computer is used, it can change the base frequency to any value from 25.00 to 99.99 Hz. In LINE SYNCH Mode the base frequency is the same as the ac mains.

In multiunit systems the System Master supplies its base frequency to all the other Test Instruments, which accept it as their base frequency regardless of the switch setting on their own TIMING GENERATOR cards.

Source Designations

Every source is identified by a 2-character designation shown in its SOURCE display. Each source is assigned the first appropriate designation by default when its Instrument is powered up. The operator can change a source's designation at any time by pressing the paddle switch below its SOURCE display.

Pressing left cyclically selects the type of source: (source must be OFF and not ENABLED).

V =	ac voltage,	K =	300 VA ac current, high resolution
I =	ac current,	G =	500 VA ac current, high resolution
IP =	parallel ac current,	l =	Parallel F2350 and F2300, 300 VA
L =	300 VA ac current,	h =	Parallel F2350 and F2300, 500 VA
H =	500 VA ac current,	T =	F2375 or F2380 Current
DI =	dc current,	U =	F2380 Voltage
DV =	dc voltage.		

Only appropriate types of sources can be selected; e.g., a dedicated voltage or current source will only change when a Slave Source is attached to the Instrument, while the F2200's convertible source can be V or I (or IP) also.

Pressing to the right cyclically selects the next available sequence designations. The standard sequence is A/B/C for ac voltage sources and 1/2/3 for ac current sources. An optional extended sequence adds R/S/T and R/Y/B (for red/yellow/blue) European designations. The multiple source designations (VM and IM) are added when the F2825 Multiple Sources option is installed and can only be selected when the F2010 Minicontroller is attached.

Source Parameters

After powerup each source's amplitude and phase angle defaults to zero, its frequency to the base frequency, its range to the lowest available, and its Ramp/Set Mode to SET. Its parameters can then be changed by pressing the paddle switches below the source's displayed values.

Amplitude is set by repeatedly lifting (or depressing) each switch, which increases (or decreases) the value of the digit immediately above it by one each time.

Phase Angle is set the same way. Lifting and depressing each switch increases (or decreases) the value of the digit immediately above it.

Frequency is changed by pressing the switch below the HERTZ display to the left, which increases it to to the next harmonic. After the tenth harmonic it returns to the base frequency.

Range is changed by pressing the switch below the RANGE display to the right, which increases it to the next value. After the highest value it changes to the AutoRange Mode (Aut shown), which automatically selects the lowest range for the specified amplitude. After AutoRange it returns to the source's lowest range.

Ramping

The amplitude and phase angle can also be changed continuously at one of several fixed rates when in Ramp Mode. Press the RAMP switch left to change to Ramp Mode, then raise (or lower) one of the paddle switches under the parameter to be changed. Its value will increase (or decrease) at a fixed rate as long as the switch is pressed.

The rate depends on which switch is pressed:

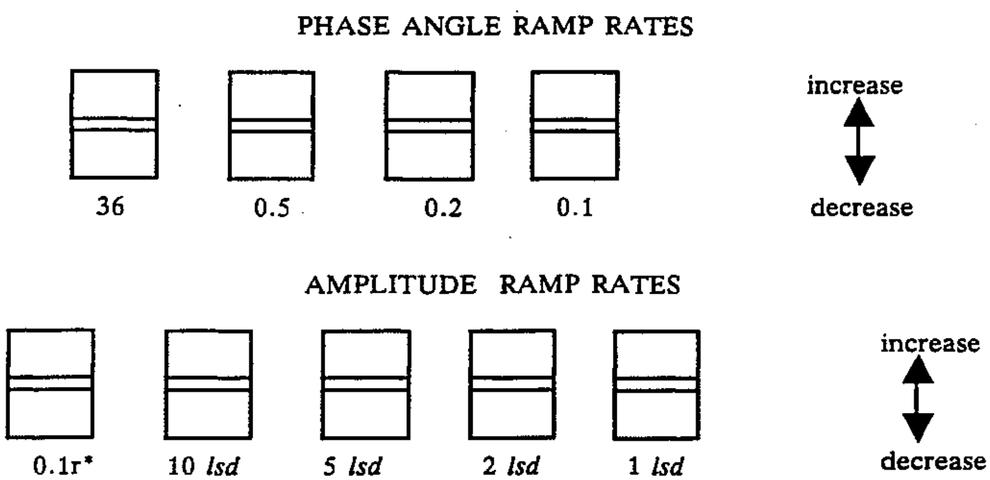


Figure 3-6. Paddle Switch Ramp Rates - Per Second

* r = selected range,
lsd = least significant digit.

When ramping in AutoRange, the value stops at the end of a range until the range has been changed. If the source is on, it will be turned off during the change.

AutoSensE Tests

An AutoSensE Test quickly and easily determines a relay's pickup or dropout setting, reach, or angle of maximum torque. Just ramp the appropriate parameter (amplitude, phase angle, or frequency) with the timer in the SENSE Mode, configured for the appropriate signal. When operation is sensed the beeper sounds, the ramp is stopped and the sources are left on with their last values shown in the displays.

NOTE: In the RAMP mode SENSE must be manually reset to make it ready for the next test.

TIMER CONFIGURATION

The timer is reset (cleared) and set to the Sense and Voltage Off-to-On Mode after powerup. In this state it only beeps when the type of signal it is configured for occurs.

Before a timed test can be run the timer must be activated and configured for the test conditions.

This consists of:

A. Selecting the desired Start and Stop Modes,

B. Selecting the type of signal to be sensed, and

C. Setting the timer's range.

When the timer stops at the end of a timed test, all enabled sources are turned off, the SYSTEM OUTPUT controls are disabled, and all displays keep their end-of-test values showing until RESET is pressed.

OPERATING MODES

The MODE switch cyclically selects the SENSE, STOP, START, or PULSE Modes when pressed to the right; and the type of signal to be sensed when pressed to the left.

SENSE Mode produces an audible beep and displays the word SENSE when the specified type of signal occurs.

STOP Mode is used for most timed tests. It starts the timer when the selected source starts (or stops), and stops it when the specified type of signal occurs.

START Mode is only used when a Phase Interface option is installed for testing autosynchronizing relays; it starts the timer when the relay operates and stops it when the zero crossings of the two signals being compared occur together.

PULSE Mode measures pulse width; it starts and stops the timer when the signal being sensed starts and stops.

External Signal Types are cyclically selected by pressing MODE to the left. Either transition of either ac or dc voltages or of dry contacts can be selected. The type of signal is indicated graphically.

Time Units is changed cyclically through SEC (seconds), MSEC (milliseconds), and CYCLES when the range switch is pressed to the right. When in MSEC the range changes to SEC automatically at one second. CYCLES counts increments of 50 or 60 Hz only as selected by the switch on the timing board.

Start Mode is switched between Sources 1 and 2 (F2100, F2200, and F2500 only) when the START switch is pressed to the left, and between Off->On and On->Off when pressed to the right. These are only effective when in the STOP Mode.

ON-OFF CONTROL

Every source can be turned on and off individually at any time by pressing the ON side of its dual-action rocker switch. The source turns on at a zero crossing. Its LED lights when the source is on.

Sources are switched into and out of the Enable Mode by alternately pressing the ENABLE side of the rocker switch. (If the source had been turned on, it is turned off.)

Enabled sources are turned on and off together when the SYSTEM OUTPUT pushbutton on any Test Instrument (and the Minicontroller) is pressed.

Source/System Xero X

Turnon times depend on the Zero X Mode: in Source Zero X each source turns on at its zero crossing, and in System Zero X they all turn on simultaneously at their respective phase angles when the System Master's REF 0 occurs.

On/Off Indications

The ON indicator above a source's ON control is lighted whenever the source has been turned on individually.

All SYSTEM OUTPUT switches are lighted steadily when the enabled sources are on (if no other source has been turned on individually), or blink when any other source has been turned on individually.

Each source's High Voltage Indicator (next to its lightning symbol) is on when the potential at the terminals exceeds 20 volts.

PARALLEL SOURCES

Up to 3 F2100 and/or F2200 and/or F2500 lower current sources can be placed in Parallel Mode by setting their source designations to IP. In Parallel Mode they act as a single source whose output is the sum of each individual source's output. The Parallel Mode can also be used by the Minicontroller and by a Host Computer.

All IP sources are controlled by the System Master's IP source. Its AMPLITUDE controls specify (and its display shows) the total current from all IP sources. Its PHASE ANGLE, HERTZ, and RANGE controls (and displays) specify (and show) the common phase, frequency, and range of each IP source. Its ON and ENABLE controls control the Slave IP sources also.

Slave IP sources show PAr ALLEL in their PHASE ANGLE and AMPLITUDE displays to indicate that their controls are disabled.

> NOTE: Maximum IP current is 64 amperes. Resolution is set by each source's range.

> NOTE: Do not use AutoRange when in the Parallel Mode.

Each IP source must be in phase with the common load. Connect all red (HI) terminals to the relay's HI (polarity) terminal, and each black (LO) terminal to the relay's LO (return) terminal.

> NOTE: If any source is not connected correctly, all the sources will indicate normal operation but the total output will be much less.

> NOTE: The System Master will not recognize an IP source error in a Slave, which will beep to indicate the error.

FAULT ROTATE

The fault rotate feature is used when manually testing 3–phase distance relays. It rotates simulated φ–N faults and Δ–potential φ–φ faults counterclockwise to the next phase(s) without having to change any source parameters or more than a single connection.

After a test has been run (and the timer reset), just press the FAULT ROTATE switch to the appropriate side, change the connection to the relay's next current phase (if only a single current is used), then start the next phase's test.

φ–N Faults

A simulated 3–phase φ–N fault requires 3 voltage sources and 1 or 3 current sources. Set up the test parameters as shown in Figure 3–7, with 1 or 2 faulted phases.

φ–φ Faults

A simulated 3–phase φ–φ fault requires 2 voltage sources in Open Δ configuration and one current source setup as shown in Figure 3–8.

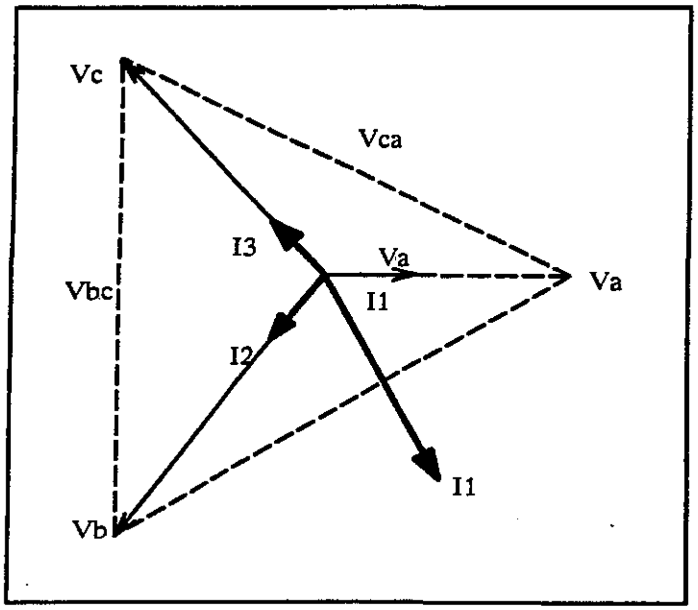


Figure 3–7. φ–N Faults.

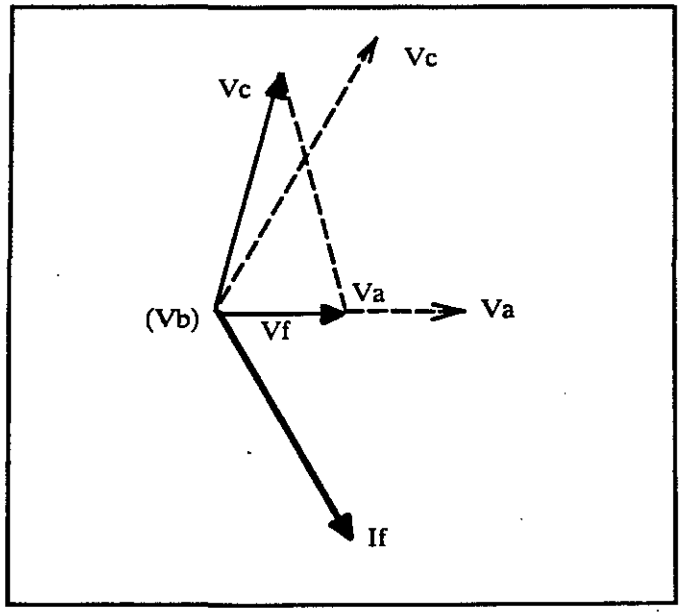


Figure 3–8. φ–φ Faults.

NOTE: Open Delta Fault Rotate
In the Open Delta Configuration, two voltage phasors are generated directly. These represent two of the three line–to–line potentials in a three phase system; the third voltage is the difference voltage. Fault Rotate will provide AB – BC – CA rotation of the faulted phase only when the generated phasors truly represent correct power system geometry.

Examples are given in the following table for VA at 0°:

Fault reduction	00%	10%	20%	30%	40%	50%	60%
VA (Vfault)	120.0	108.0	96.0	84.0	72	60.0	48.0
VB	120.0	117.1	114.5	112.0	110.0	108.2	106.7
VB Angle (φ)	60.0°	62.5°	65.2°	68.0°	70.9°	73.9°	77.0°

Using the correct power system phasor values for VA and VB results in the following fault rotation for Vab –Vba –Vca.

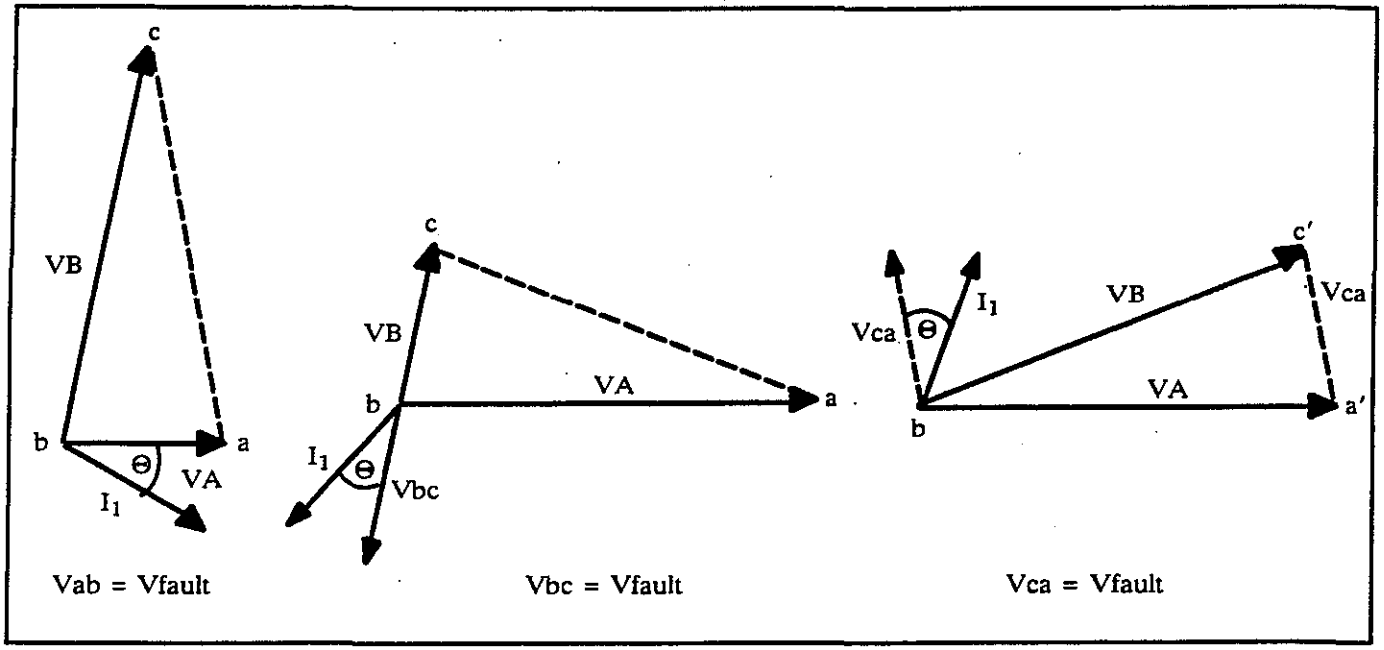


Figure 3–9.

VA	40.0V @ 0.0°	105.8V @ 0.0°	105.8V @ 0.0°
VB	105.8V @ 79.1°	40.0V @ 79.1°	105.8V @ 21.8°
VB–VA	105.8V @ 100.9°	105.8V @ 158.2°	40.0V @ 100.9°
I1	1.0A @ 330.0°	1.0Z @ 229.1°	1.0A @ 70.9°

The phase relationship of I1 = Ifault to the faulted phase (regardless of rotation) is constant as shown.

MINICONTROLLER

The F2010 Minicontroller extends the control capabilities of the Test Instrument it is connected to (and to 1 or 2 other Test Instruments in a multiunit system if they all have the F2825 Multiple Sources option.) The Minicontroller cannot initialize unless it is connected to the System MASTER.

Initialization

Press the Minicontroller's alternate action POWER pushbutton once to initialize the Minicontroller. This lights its ON indicator and the Instrument's REMOTE indicator, and loads the present values of the sources' parameters into both A and B Set Value registers.

On/Off Control

Pressing SYSTEM OUTPUT turns all enabled sources on and lights its SYSTEM OUTPUT ON indicator, or turns them off along with the indicator, just like the SYSTEM OUTPUT control on every Test Instrument.

Selecting A Source

A source must first be selected before its parameters' values can be changed or saved for dynamic testing. Press the Source Switch to select either Source 1 (SRC#1), Source 2 (SRC#2), or BOTH. BOTH can only be selected when FREQ is selected.

Selecting A Parameter

Once a source is selected its parameter values (shown in its displays) can be changed. Press the Parameter Switch to select either its amplitude (AMPL), phase angle (PHASE), or frequency (FREQ).

Changing A Parameter Value

The value of the selected source's selected parameter is changed by rotating the knob. Clockwise rotation increases the amplitude, frequency, and the phase angle (in a lagging direction), and vice versa. The present value is always shown in the source's displays. The rate of change depends on the source's range (automatically set by AutoRange) and the RESOLUTION control, which selects either COARSE or FINE. COARSE changes the value 128 least significant digits (lsd's) per revolution, and FINE changes it only 1/8 as much (16 lsd's/revolution). In the COARSE mode the knob is velocity sensitive; turning the knob faster causes greater change.

Saving Parameter Values

When the Minicontroller is turned on, both Set Value registers A and B are initially loaded with the amplitude, phase angle, and frequency values from both sources, and A is selected. Pressing the SET VALUE switch replaces all the values in A with the Instrument's present values, and selects B. If the F2820 Δ Value/Δ Time option is not installed, pressing SET VALUE again replaces all the values in B with the Instrument's present values and selects A. Thus two sets of parameter values can saved for dynamic testing.

If the F2820 option is installed, pressing SET VALUE when B is selected saves the present values then selects C for saving a rate-of-change value. The selected source's selected parameter's display also changes; to 'N' CY for amplitude and phase angle, where 'N' = the number of cycles between 1-lsd steps, or 'N' SEC for frequency, where 'N' = the number of 0.01 Hz changes per second. The knob changes 'N'. Pressing SET VALUE saves the rate-of-change value and selects A. The value in C remains available after the Minicontroller has been turned off and back on again. Setting 'N' to zero produces a step change between values A and B.

On FREQ ramps only, an intermediate timer start value can be set. With register C selected, pressing the HERTZ/RANGE switch to the left will cause the A and B indications to flash alternately and the RANGE display to read "StA" (Start). A value between A and B may now be set via the knob and stored by pressing SET VALUE again. When the test is run, the times will start as the frequency reaches the set value and will stop when the relay operates.

Dynamic Tests

Pressing the Δ VALUE pushbutton initiates a Dynamic Test and disables all the Minicontroller's controls except Δ VALUE. The test changes the selected source's selected parameter from its present value (shown in its display) and stored in A or B (whichever is selected), to the value stored in the other Set Value register. The change occurs instantly (at a zero crossing), or at the rate in C when the F2820 is installed.

The timer is started when the source's value equals the stored value, and stopped when a signal is sensed. Pressing Δ VALUE while the test is in process aborts the test and stops the timer. Pressing Δ VALUE after the timer stops resets the timer, reactivates the controls, and restores the Set Value selection.

See the F2010 Minicontroller Manual for more specific operating and application information.

PHASE INTERFACE OPERATION

GENERAL DESCRIPTION

The Phase Interface Option permits the evaluation, testing, and calibration of breaker advance timing of automatic synchronization relays. The F2200 or F2500 Instrument with Dual Phase Interface Option F2845 is used in conjunction with the F2010 Minicontroller. The F2100 Instrument with Phase Interface Option F2835 is used in conjunction with an external FDF Dynamic Frequency Source.

INTRODUCTION

Automatic synchronizing relays monitor slip frequency FS, the difference frequency between a generator and the bus. When a generator is to be brought on line, the relay determines if FS is small enough and changing slowly enough to avoid generator damage or line disturbances; if so, it computes when in-phase synchronization will occur and produces a circuit breaker close signal sufficiently far in advance so that the breaker contacts will close at synchronization.

All types of automatic synchronizing relays can be investigated and calibrated easily and accurately by a Doble Model F2200 or F2500 with the Dual Phase Interface option and the F2010 Minicontroller. One F2200/F2500 voltage source supplies a variable frequency, controlled by the F2010. The second voltage source supplies the constant reference frequency. Another configuration is to use a Doble Model F2100 equipped with the F2835 Single Phase Interface option for the reference frequency and the Doble Model FDF Dynamic Reference Source as the variable frequency. To insure a stable reference frequency for both instruments, the F2100, F2200, F2500 and FDF all provide a precise 50/60 Hz reference signal from their crystal oscillator.

The Phase Interface measures zero crossings, and determines when the two signals are synchronized.

Synchronization is detected when both zero-crossings occur at the same time, and indicated by stopping the Timer. Because these signals are very brief (determined by the setting of the accuracy controls on the Phase Interface board), the possibility of both of them occurring together with enough overlap to be detected depends on the slip frequency. Circuit breaker advance time tests must be made at low slip frequencies to assure detection. If the slip frequency is too high the Phase Interface may not detect synchronization and the Instrument Timer will not stop. The Phase interface may, however, detect synchronization at a later time and report a close time higher than the set time by one or more slip periods.

THEORY OF OPERATION

The Phase Interface Circuits consist of Digital Signal Generation (single or dual channel), Microprocessor input/output ports, Pulse Width Generation and Selection Circuits, and Zero-Crossing Pulse Coincidence Detection Circuits which generate the STOP command for the timer.

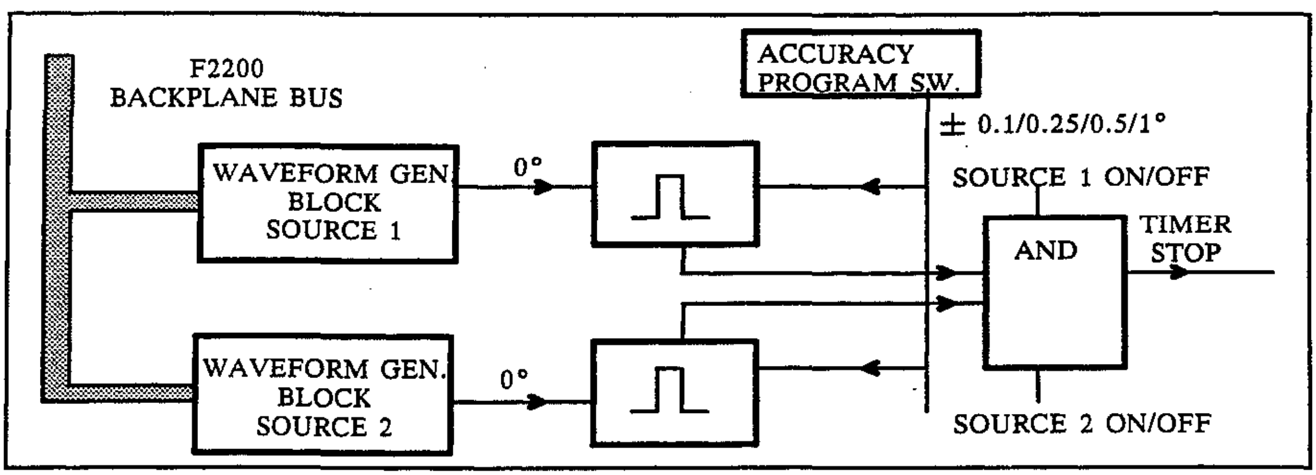


Figure 3-10. F2845 Dual Phase Interface Block Diagram.

Waveform Generation Blocks

The Waveform Generation Blocks (source 1 and 2) operate in synchronism with the waveform generator board in the F2000 instrument. The waveform blocks store the sinewave coefficients that are processed by a digital to analog converter (DAC) to produce a precise sinewave. In the phase interface only the 0.0 degree zero crossing pulses are used. These zero crossing pulses are exactly synchronized with the pulses on the F2000 waveform board. The 0.0 degree pulses are exactly in phase with the output analog waveform.

Pulse Width and Coincidence Detector

The zero crossing pulses are passed to the pulse width circuit. The pulse width circuit sets the zero crossing input pulse at four different pulse widths providing ± 0.1 degree, 0.25 degree, 0.5 degree, and 1 degree phase accuracy. A switch at the top of the phase interface board may be accessed when the top cover is removed. Note that the firmware only changes the pulse width after the switch is set and the system is powered up. Changing the setting after the system is turned on will not change the accuracy value, because the firmware will not recognize switch changes after power-up.

SWITCH SETTING	PULSE WIDTH	SLIP RATE LESS THAN	PHASE ANGLE ACCURACY
1	4.2 µs	0.03 Hz	0.1°
2	10.5 µs	0.075 Hz	0.25°
3	21.0 µs	0.15 Hz	0.50°
4	42.0 µs	0.30 Hz	1.0°

In the coincidence detector the two zero crossing pulses are logically "AND-ed". When both pulses coincide, a timer STOP signal is generated. The timer will have been started by the breaker advance signal from the automatic synchronizing relay. The timer will display breaker advance time in mS/sec/cycles.

Phase Interface accuracy is set by defining pulse width (of the zero crossing detection pulses). Pulse width affects the maximum slip frequency at which coincidence may be detected.

Narrower zero crossing pulses are required for higher accuracy at low slip frequencies. To insure coincidence detection at higher slip frequencies, wider zero crossing pulses are required, with accuracy being correspondingly lower. The time interval during which coincidence is detected is related to pulse width. With ± 0.1 degree accuracy (4.2 µs pulse width) setting, zero crossings must occur within 4.2 µs of each other for coincidence detection. At the ± 1 degree setting (42 µs pulse width) zero crossings must occur within 42 µs for coincidence detection.

A lower accuracy setting (longer zero crossing pulses) will result in coincidence detection earlier, resulting in different breaker advance time being reported. This effect of the width of the coincidence detection window and the slip period are discussed at the end of this chapter.

Example:

A computer model was used to determine the relationships between zero crossing pulse width and slip frequency. Results may be verified using the F2200 or F2500 instrument.

The model assumes that two sine waves are in precise phase coincidence at 0 degree when T = 0.

Based on a slip frequency of 0.2 Hz (60.00Hz and 59.80Hz) the signals cross zero every 2.5 seconds. The time difference between zero crossings of the two signals must be within the zero crossing pulse width for detection to occur.

If the signals were in phase when T=0, they will cross zero at 2.5/5.0/7.5 seconds (etc). The data for the 3rd (5 second) point indicates 0.0 μs time difference, clearly within the 0.1 degree (4.2 μs) pulse width; coincidence would be detected. Using the 1 degree (42 μs) setting the coincidence detector will operate for all noted cases, although at less accuracy. The F2000 will display different results for the same slip frequency with different accuracy settings.

60 HZ ZERO X	59.8 HZ ZERO X	TIME DIFFERENCE
4.9916667 seconds	4.9916388 seconds	27.9 μs
5.0	5.0	0.0 μs
5.008333	5.0083612	27.9 μs

An automatic synchronizing relay places a generator on line by providing a breaker closure signal in advance of its predicted in-phase synchronization point, to compensate for the circuit breaker's operating time. Breaker contacts should close at the zero-crossing when the generator and bus are within specified synchronization. The following general procedures outline a suitable test method to establish breaker advance time.

Using the F2200 or F2500 and F2010 With the F2845 Dual Phase Interface

- Consult the manufacturers instructions to determine the relay connection. Connect the SOURCE 1 and 2 outputs to the relay bus and generator voltage inputs. Connect the relay "CLOSE" output terminals to the SENSE terminals of the F2200 (or F2500).
- Set the Accuracy control on the Phase Interface Board, then power up the instrument.
- Set the timer to the START Mode and select the appropriate SENSE conditions.
- Set F2200 Source 1 and 2 Voltage, and Source 1 at 60/50Hz (the base frequency).
- Using the F2010, set Source 2 frequency for the desired slip frequency.
- ENABLE SOURCE 1 and 2.
- Using the F2010 OUTPUT ON control, turn both enabled sources ON, starting the Test.

The relay under test will start the timer with its breaker advance (close) signal; when coincidence occurs (within the accuracy selected), the Phase Interface will stop the timer. The displayed time must be compensated for the effect of coincidence window and slip speed to calculate the close angle error of the relay (see end of this chapter).

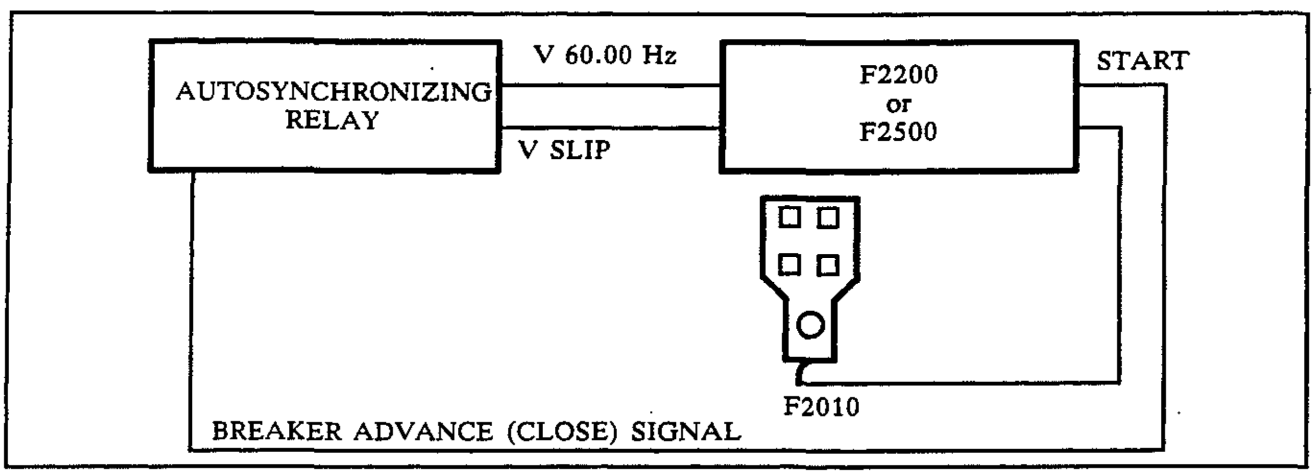


Figure 3-11.

Please refer to the F2010 Minicontroller Manual for operating information. With these interconnections, a slip frequency between voltage Source 1 and 2 may be set, and breaker advance timing measured.

Using the F2100 and FDF With the F2835 Single Phase Interface

Operation is functionally similar using the external FDF Dynamic Frequency Source. The F2100 voltage Source is set to 50/60Hz. The FDF is set to provide the desired slip frequency. The FDF internal timer STARTS when the relay "breaker close" output occurs, and STOPS when phase coincidence at zero degrees occurs.

In F2100 operation with an external FDF equipped with a Phase Interface, an FDF identification bit is generated simply by connecting the Sync cable and powering-on the Dynamic Frequency Source. The FDF ID bit is displayed on the F2100 Front Panel indicators. The F2100 micro-processor changes from internal line synchronization, and selects the 50/60 Hertz synchronization square-wave supplied by the FDF. The FDF square-wave is used to drive the Phase Locked Loop (PLL) circuitry located on the Timing Generator, so that both instruments are in synchronization. The F2100 Timer is inhibited in this mode. The F2100 reference zero crossing pulse is transmitted to the coincidence detection circuitry located in the FDF. When coincidence is detected, the FDF Timer Stop signal is generated.

F2100, FDF Automatic Synchronizer Test

Connect the SYNC INTERFACE of the FDF to the FDF INTERFACE of the F2100 as shown below, using the Interface Cable supplied. Power up both instruments. Consult the manufacturer's instructions to determine the relay's connections. Connect the generator input to the FDF output. Connect the line (bus) input to the F2100 Source 1 output. The "breaker close" output is connected to the START or STOP terminals of the FDF's timer, depending on the test procedure.

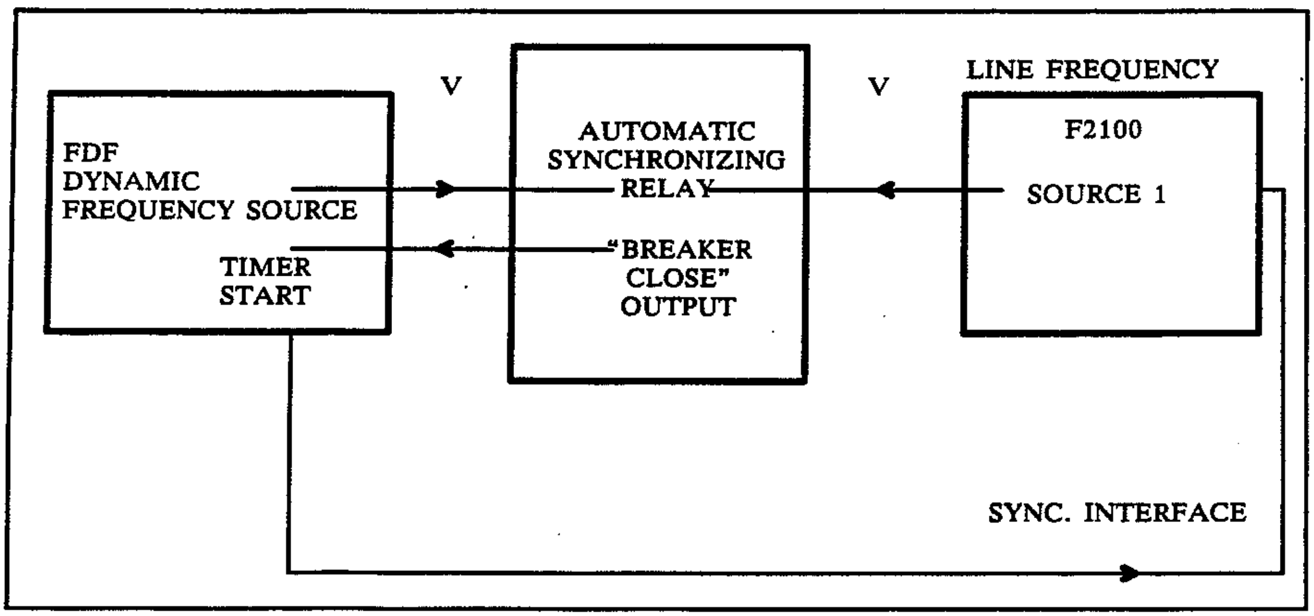


Figure 3-10.

Circuit Breaker Advance Time

FOR THE F2100 WITH THE F2835 OPTION AND THE FDF THE FOLLOWING PROCEDURE IS RECOMMENDED:

NOTE: The Standard Phase Interface circuit in the FDF provides $\pm$ 1° ACCURACY zero crossing synchronization. The FDF Precision Phase Interface option, can be set to $\pm$ 0.1°, $\pm$ 0.25°, $\pm$ 0.5°, or $\pm$ 1° by a switch on the phase interface circuit board. When using the FDF with the F2100, both phase interface accuracy switches must be set to the same accuracy settings (according to the slip frequency). If a Standard Phase Interface board is installed in the FDF, the F2835 phase interface in the F2100 must be set to $\pm$1° accuracy.

Switch Setting	Zero Crossing Accuracy	Max. Slip Frequency
1	± 0.1°	< 0.1 Hz
2	± 0.25°	< 0.2 Hz
3	± 0.5°	< 0.45 Hz
4	± 1.0°	< 0.5 Hz

A. **Setup and Powerup the Relay, FDF and F2100.** Connect the relay's "breakers close" output terminals to the FDF timer's START terminals. Set the F2100 source 1 OUTPUT to the normal relay operating voltage and turn it ON.

B. **Prepare the FDF** by setting its controls as indicated:

1. OUTPUT = normal relay operating voltage (same as F2100).
2. LINE FREQUENCY = 60.00 Hz ± slip frequency.
3. SWEEP RATE = 000 Hz/s (no change of frequency).
4. DURATION = 000 CYCLES
5. MODE = SWEEP.
6. TIMER MODE = SYNC.
7. RANGE = 9.99 SECONDS.
8. START Sense = **up** if N/O contact or SCR off, **down** if N/C contact or SCR on.
9. STOP Sense = **up.**
10. Output Switch = ON.

C. **Determine the Advance Time** by pressing and holding the FDF TEST button, then activate the relay. The relay should trip (starting the timer) when it predicts that phase synchronization will occur at the end of the circuit breaker's operating time. The timer operation is stopped when the two signals are in phase. Release TEST, record the OPERATING TIME as the "As Found" circuit breaker advance timer. Reset the timer, and turn off all Sources for safety.

CALCULATING THE ACCURACY OF THE RELAY UNDER TEST

As mentioned earlier, the relay advance time element has a predictive function and is not a timer. Therefore the criteria for judgement of accuracy cannot be time alone. The important issue is the angular error at circuit breaker contact closure.
This can be found from:

$$\text{CAE close angle error} = \frac{\left[\Big((\text{Set time}) - (\text{Measured time} - 8\text{ msec})\Big) \times (\text{SLIP FREQ} \times 360)\right]}{1000} + \text{Z.C.A.}$$

where

Set time = relay set close advance time in milliseconds

Measured time = time read from test instrument timer in milliseconds

SLIP FREQ = frequency difference between test sources (expressed as a positive number) in Hz

8 msec is the average measuring delay since synchronism is only detected at zero crossing but can occur anywhere on the waveform.

Z.C.A. = set zero crossing accuracy in degrees.

ERROR DETECTION & HANDLING

The microcomputer is constantly checking its own operation, the Instrument's operation, and communication between Instruments. If a problem is detected, it stops and notifies the operator by beeping and displaying an error message(s).

Three types of errors are detected — Network Errors (in multiunit systems), Internal Errors (within the Instrument), and Source Errors (usually caused by too large a load impedance ... shorted voltage output ... open current output ... etc.).

Network Errors

Network Errors are fatal errors (they stop the microcomputer) due to a communication error on either the IEEE-488 Bus or SYNC Cable. The Instrument that first detects the problem stops and displays a code message that specifies the cause of the error, and stops the other Instruments, which display a nEt error message.

To recover from a Network Error, press any control on the front panel of every unit. The first unit becomes the Controller-in-Charge and System Master.

All units go into the Power On state (show Pon in their TIME display) and, when they are all ready, become active again.

If this does not clear the error, switch all instruments OFF. After five seconds POWER UP in sequence.

If the error persists, or if recovery cannot be achieved, record all the error codes and messages, then call Doble. See Appendix A for a listing of Network Errors and messages.

Internal Errors

Internal Errors are fatal errors due to a hardware or software malfunction. These halt the Instrument and display an error code in the same way that network errors are displayed.

Recovery can be attempted in the same way, but it probably will not be successful — the Instrument usually requires servicing. Be sure to copy the error messages and codes before calling Doble.

Figure 3-5 shows a typical display for an internal system error. SOURCE 1 shows SY (for System) followed by an error code and the word Error. SOURCE 2 shows the word AT, followed by the internal address of the error.

Some examples of Internal Errors that may be detected are listed below. See Appendix A for a more complete listing.

A. Watchdog Reset — occurs when the software enters an infinite loop, or attempts an operation that requires too much time. CODE = 0001

B. Bus Timeout — occurs if the software has an error or a pcb board is missing. CODE = BUS

C. Unexpected Interrupt — may be due to noise. CODE = 500 × (× is variable)

D. Memory Error — couldn't read the sine wave values. CODE = 300 ×

E. Timer Error — occurs if the timer isn't configured correctly. CODE = 200 ×

F. Amplifier Error — no amplifier detected at initialization. CODE = 9000 ×

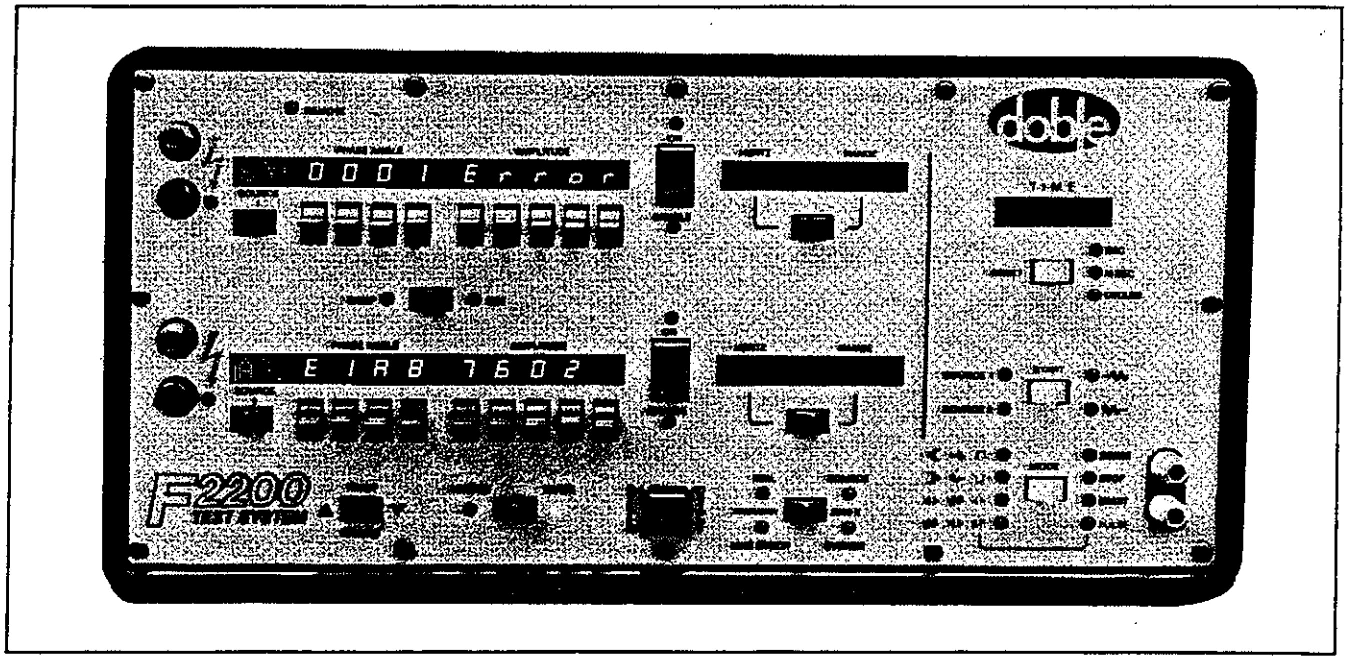


Figure 3-11. Typical Internal System Error Message Display.

Source Errors

Source Errors can occur during normal operation from a variety of reasons. They do not turn the Instrument off, but may turn the source off depending on the type of error. When a source error occurs the beeper sounds and an error message flashes in the SOURCE display of the source in error.

Source errors include:

A. The 'Warm Up' message, when an Instrument is first turned on.

B. An 'Overload' message, when the source cannot drive the load at the specified amplitude.

C. A 'Ground Fault' message, when an F2300/F2300A/F2350 is not connected correctly.

D. An 'Overtemperature' message if an F2300/F2300A/F2350 gets too hot.

E. A 'Position' message if the F2410 isn't level enough.

F. A 'Power Supply' message if the power supply can't provide the required voltage.

G. A 'Range Error' message if the F2300A is in the wrong tap.

H. A 'Thermal Management' message while an F2300/F2300A/F2350 is turned off when its amplitude is at 100 or more amperes.

SECTION IV
PRINCIPLES OF OPERATION

*

INTRODUCTION

Every F2000 Test Instrument, and any attached Slave Source, is controlled by the Instrument's internal microcomputer. This section describes the organization of the Instruments and how the internal microcomputers control instrument operation from front panel controls, a F2010 Minicontroller, or a Host Computer.

Organization

Every F2000 Test Instrument consists of one or two Active Sources Power Amplifiers that produce precision ac test signals, a Digital Sine Wave Generator that provides the reference input to each Power Amplifier, a Timer that senses external events and measures elapsed time, a Front Panel that provides local control and displays the present state of the Instrument and its sources, and an F2000 Microcomputer that controls the Sine Wave Generators, the Power Amplifiers, the Timer, and the Front Panel indicators and displays. See Figures 4–1 and 4–2.

The Microcomputer obtains its control information from the Front Panel controls, or from an external Host Computer or F2010 Minicontroller through serial communication ports. It also communicates control and status information with other Test Instruments over an IEEE 488 Bus when part of a multiunit system. Frequency and timing signals are transmitted by a SYNC Cable.

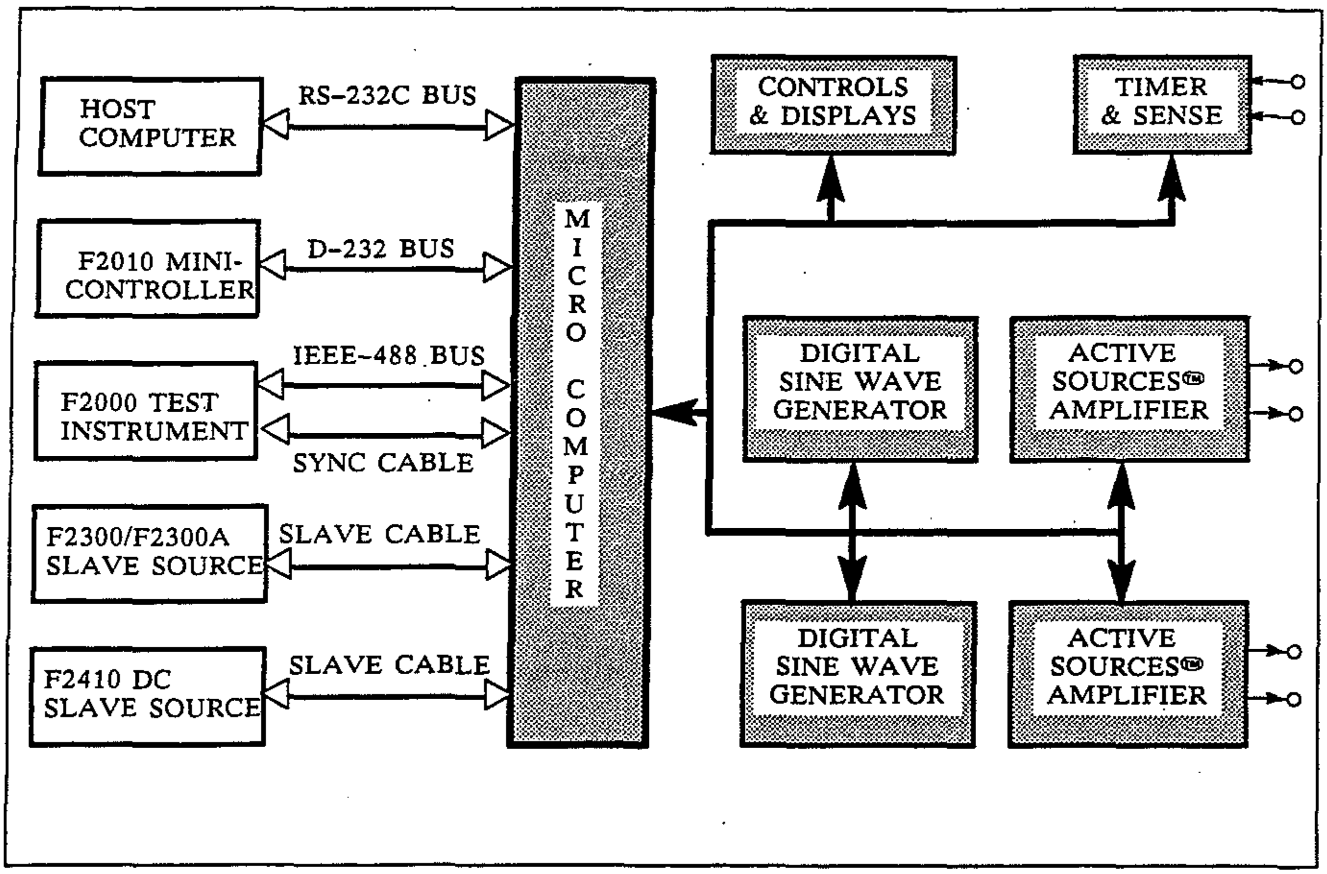


Figure 4–1. F2100/F2200/F2500 System Configuration.

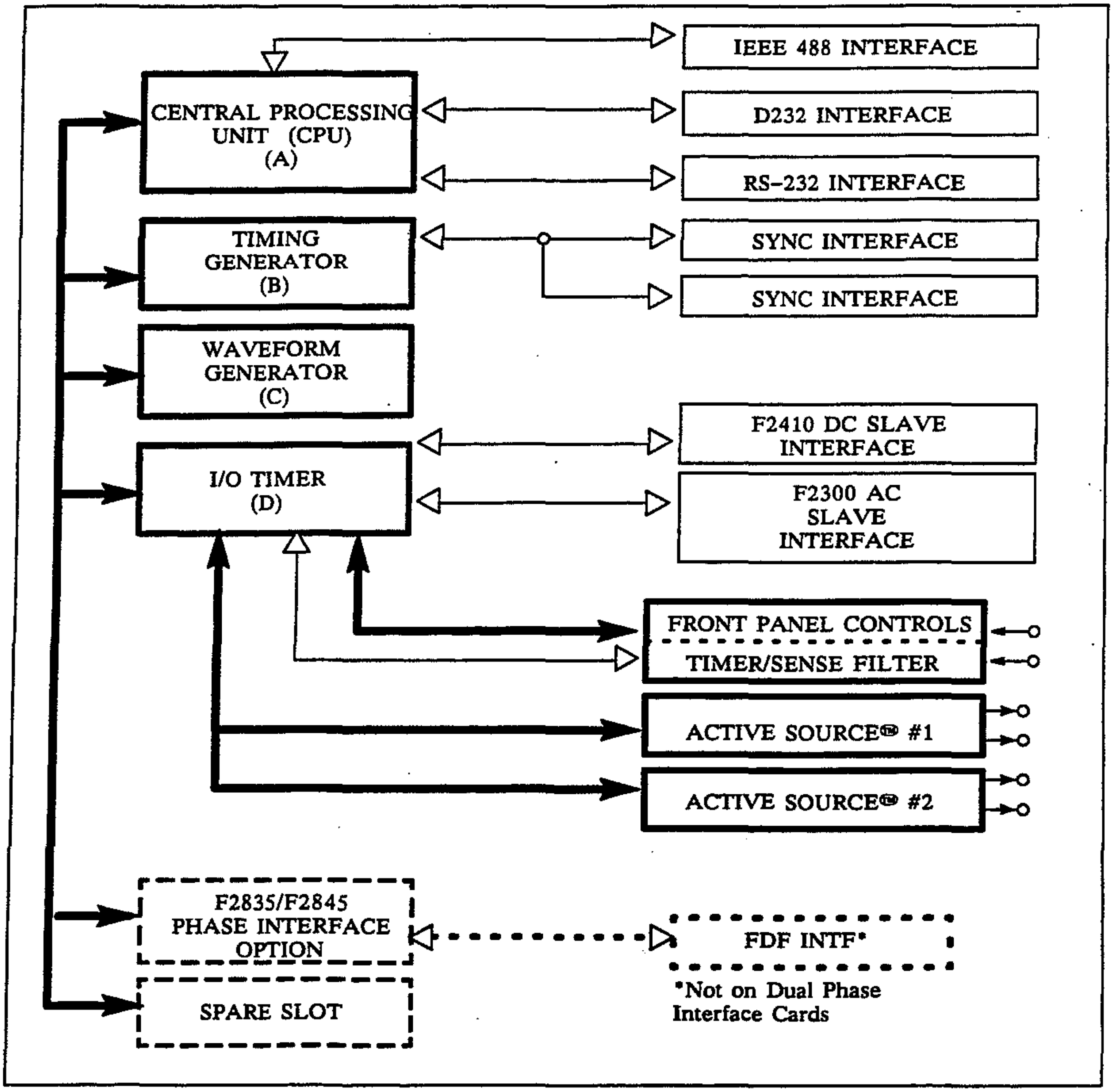


Figure 4-2. F2100/F2200/F2500 Functional Block Diagram.

The F2350 is similar to the F2100 and F2200 except it only has one Active Sources® High Power Amplifier.

All signal generation and control information for AC and DC Slave Sources is supplied by the Test Instrument they are connected to. The F2000 Test Instruments have a 6-slot card cage that contains four standard printed circuit boards, or "cards". These contain the Microcomputer, the internal inter-faces to the Front Panel and the Active Sources Power Amplifier(s) that produces the test signal(s), and the external interfaces to any other Test Instruments, any Slave Source, a Minicontroller, and a Host Computer. The other two slots accept any optional special function cards.

The four standard cards are:

A. Central Processing Unit. Controls and evaluates all communication between other Test Instruments, a Minicontroller, a Host Computer, and the Front Panel; determines the content of all messages to the other cards that generate and control the test signal(s); and provides external interfaces for communicating with a Host Computer, and Minicontroller.

B. Timing Generator. Produces (or reproduces if a Slave in a multiunit system) the system reference (REF 0), base frequency, and the timing signals used to generate the test signal(s), turn the source(s) on and off, and start or stop the Timer; and provides external SYNC interfaces for synchronizing all operations with other F2000s.

C. Waveform Generator. Generates one or two precision sine waves for the Instrument's (or its Slave's) Power Amplifier(s), and the amplifier scaling signals.

D. I/O Timer. Monitors the front panel controls and generates an interrupt whenever a change occurs, provides the signals that operate the displays and indicators, effects on/off and range control for both sources (internal or Slave), operates the Timer, and provides interfaces for the F2300 (or F2300A) and F2410 Slave Sources.

OPERATION

The Central Processing Unit (CPU) is the heart of the F2000 Microcomputer. It contains an 80186 microprocessor, a 128 Kb read-only memory (ROM) for permanent storage of the firmware that controls the Instrument, a 80 Kb random-access memory (RAM) that contains buffers for temporary message storage, a controller and interface to the F2000 Bus, and controllers for the IEEE 488, RS-232C, and D232 interfaces.

Turnon

When first turned on the firmware performs a poweron (Pon) check, checking that the microprocessor and memory operate correctly, the Waveform Generator is operating, the Power Amplifier(s) and other cards are present, and that the phase lock loop is operating.

If all these tests are passed it initializes the Instrument, then checks if it is part of a multiunit system. If not it goes into the warmup (WU) state until the amplifier power supply warms up, then goes into a wait loop until an interrupt occurs.

If the Instrument is part of a system (the IEEE 488 Bus and SYNC Cable are connected to another Instrument), it either becomes the Controller-in-Charge (with bus address 00) if it is the first unit turned on or requests its bus address from the Controller-in-Charge, then goes into the warmup state. When the Controller-in-Charge determines that all the units in the system have been turned on and are warmed up, it activates the system. All the Instruments then turn off their WU displays and go into wait loops.

Interrupt Operation

F2000 Test Instruments (and their Slave Sources) maintain their status quo until an interrupt occurs. Interrupts occur whenever a front panel control is changed or an external operation is sensed (which generates a message from the I/O Timer board), or a message is received from another Instrument, the Minicontroller, or a Host Computer.

When an interrupt occurs the F2000 Microcomputer evaluates it to determine what action to take. If an abort is specified, the message buffers are cleared (stopping any action in process) and the source or sources are turned off. Other possible actions include communicating the message over the IEEE 488 Bus, storing and/or evaluating the message's information, or using the information to change the state of some part of the Instrument or its Slave.

TEST SIGNAL GENERATION & CONTROL

The Microcomputer receives source control data and parameter value messages from either the Front Panel controls, the Minicontroller, or the Host Computer; processes the information to develop the required change-of-state messages; and transmits these to the appropriate Digital Sine Generator on the Waveform Generator card at the proper time.

Each Digital Sine Generator develops a precision analog sine wave at the specified amplitude, frequency, and phase angle. This is applied to an Active Sources Power Amplifier, which develops the output voltage or current test signal.

The Microcomputer also receives status, range, and error messages from the Power Amplifiers and Output Controls via the I/O Timer. This data is used to communicate operating information and error conditions to the operator by transmitting messages to the I/O Timer that light the appropriate Front Panel indicators and/or sound a beeper. The messages can also be transmitted to other Test Instruments in a networked system and to the remote Host Computer.

Sine Wave Generation

Incremental values of a sine wave at every tenth of a degree are stored in a read-only memory (ROM) on the Waveform Generator board. The Microprocessor transfers these coefficients, offset by any phase angle values, to two random-access memories (RAM), one for each Digital Sine Generator. At the fundamental frequency each RAM contains the values for every 0.1 degree at the base frequency. In the second harmonic every other value is transferred, resulting in values for every 0.2 degrees, etc.

The RAMs are strobed by a chain of clock pulses from the Timing Generator. Each pulse copies a value from the RAM into an associated digital-to-analog converter (D/A) and increments a pointer to the next succeeding value. When all values have been transferred the process starts over again.

The D/A converters change the digital values to their analog voltage equivalents, producing a stepped approximation of a sine wave. Figure 4-3 shows the output of the D/A for every ten degrees.

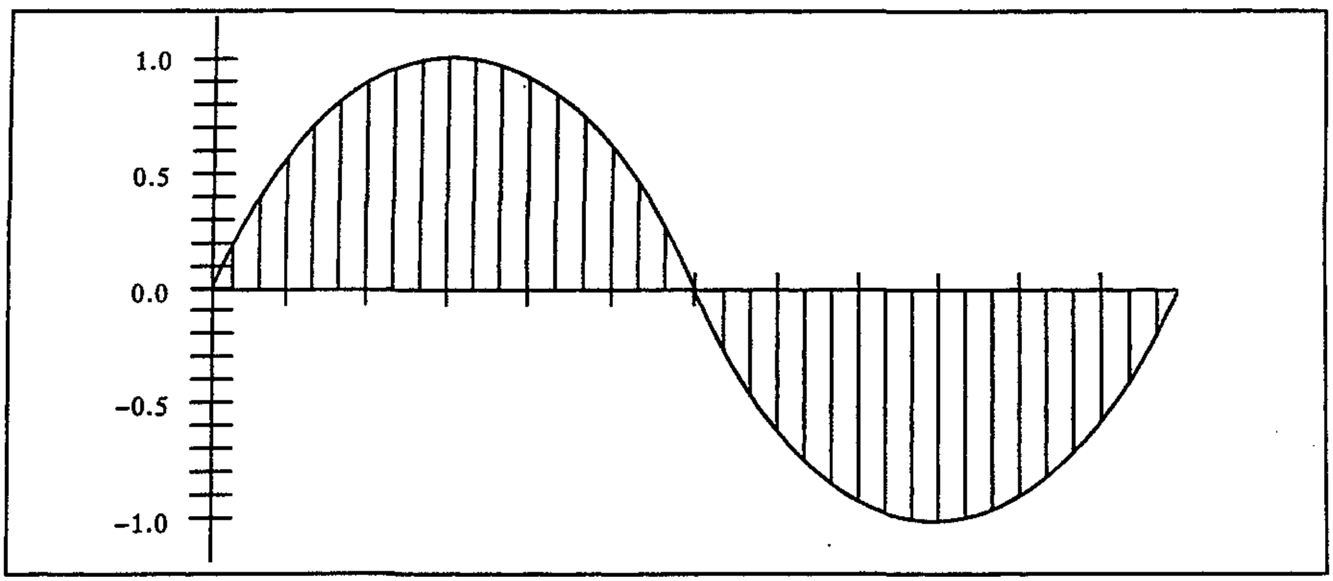


Figure 4-3. Output of the D/A for every 10° at 50/60 Hertz.

Amplitude Control

The maximum output of each D/A occurs at 90.0 degrees, when the digital value (1.000) equals a precision reference potential. The D/A thus produces a stepped sine wave of constant rms amplitude at the specified frequency and phase angle.

This signal is applied to the reference input of a multiplying D/A converter (XD/A). The desired output amplitude (a percentage of the full scale amplitude at any range) is applied to the XD/A's digital input. The output of the XD/A is therefore a stepped sine wave whose rms amplitude equals the specified rms amplitude of the source at its specified range.

The Microcomputer computes the desired amplitude from the type of source, its range, and a specified amplitude. The amplitude can be specified by the source's AMPLITUDE switches, a Minicontroller, or a Host Computer. It is always shown in the source's AMPLITUDE display.

The output of the XD/A is filtered and applied through an analog switch on the I/O Timer to an Active Sources Power Amplifier.

The amplifier's output is coupled to the load through an impedance matching transformer. Negative feedback keeps the output amplitude proportional to the precision input. Different ranges are provided by taps on the secondary, which are selected by relays.

Turnon/Turnoff Control

Each source is turned on or off by the Microcomputer, which controls an analog switch at the input to the amplifier. The source can be controlled individually by its ON switch, or, together with other sources, by the SYSTEM OUTPUT pushbutton in conjunction with each source's ENABLE switch. Sources can also be turned on or off by the F2010 Minicontroller or a Host Computer. Each of these methods starts the turnon process according to the ZERO X mode, either SOURCE or SYSTEM.

In SOURCE ZERO X mode, each source is turned on at its positive or negative zero crossing. If two sources' phase angles are set to 0° and –75°, the second will start 75° after the first one. Amplitude changes on each source take place at each sources individual SOURCE ZERO.

In SYSTEM ZERO X mode all enabled sources are turned on simultaneously at the system's 0° reference REF 0. If two sources are set to 90° and –30°, they both start at the same time; the first at its maximum positive amplitude and the second at half its maximum negative amplitude. All amplitude changes occur simultaneously at SYSTEM REF 0.

Phase Angle Control

Phase angle relationships are obtained by using a specified phase angle, ϕ, to offset the source's RAM pointer. The phase angle is defined by the source's PHASE ANGLE switches, an F2010 Minicontroller, or a Host Computer. The angle is always shown in the source's PHASE ANGLE display and represents the offset from the systems reference, REF 0.

Phase angle changes always occur at REF 0.

Frequency Control

Frequency is controlled by the rate of the clock pulses that interrogate each source's RAM, and the source's selected harmonic. The clock pulses are obtained from four references, two fixed and two variable. The two fixed references, XTAL and LINE SYNC, are the Instrument's base frequency, and are selected by the FREQUENCY switch.

XTAL produces 50 or 60 Hz clock pulses, selected by a switch on the Timing Generator. LINE SYNC synchronizes the 50/60 Hz clock pulses to the ac power mains' zero crossings.

If the Instrument is part of a multiunit system, the System MASTER provides the clock and system reference pulses to all SLAVE units to synchronize the frequency and operation of all ac sources and, even if the frequency of the MASTER is varied, all SLAVE units will track the frequency of the MASTER unit.

A crystal controlled oscillator on the Timing Generator provides (all fixed and) variable frequency clock pulses. Its output is divided a number of times to produce the correct clock frequency. The nominal base frequency of the system (50/60Hz) is simply the default setting of the variable frequency clock. The standard crystal provides an accuracy of ±0.01%. An optional F2850 Precision Frequency Reference increases the accuracy twenty-fold, to ±0.0005%.

In Remote Mode either the Minicontroller or a Host Computer can change the MASTER clock frequencies to achieve system frequencies from 25.00 to 99.99 Hz. They can also change the harmonic to provide a source or system frequency of 100.0 to 600.0 Hz.

ACTIVE SOURCES® POWER AMPLIFIERS

F2000 voltage and current sources use Active Sources Power Amplifiers to produce low-distortion sine waves with precise amplitude values and phase angle relationships to insure accurate, repeatable calibration and consistent test results. They produce these with better than ±0.5% accuracy under normal ambient conditions, and never exceed ±1% error over the maximum ambient temperature range (0°–50°C) and mains voltage variations (95–132 V @ 60 Hz or 190–260 V @ 50 Hz) that characterizes field testing conditions. Doble's factory acceptance criteria for amplitude accuracy is much tighter — only ±0.3% deviation for worst-case conditions of load, line voltage, and ambient temperature combined!

> NOTE: At output frequencies below 50 Hz the output voltage of both voltage and current sources capability decreases linearly to 50% at 25 Hz.

General Principles

Doble's Active Sources Power Amplifiers consist of wide bandwidth high-power analog amplifiers connected in a negative feedback configuration. Their input is a low distortion sine wave of precise amplitude from a Digital Sine Generator. Their output is coupled to the load by a tapped transformer, allowing a wide range of load impedances to be driven in complete isolation from other system outputs.

The output is constantly monitored to provide a negative feedback signal that accurately represents the actual test signal applied to the load, including any clipping, phase shift, or distortion introduced by the load.

Voltage sources are monitored by a resistive divider across the output, while current sources are monitored by a series shunt. See Figure 4-4.

The feedback signal is an analog of the output. It is compared to the reference signal at the input, or summing junction, of the amplifier. When the output deviates from the correct value, a difference (error) signal results. The error signal drives the amplifier so as to correct the difference, keeping the output constantly equal to the input. The rate at which the amplifier responds is far greater than the signal frequency, so the error correction is extremely rapid (and virtually undetectable when measuring the output).

Since the negative feedback signal is obtained from either the output's voltage or its current, that is the parameter that remains constant with respect to the input.

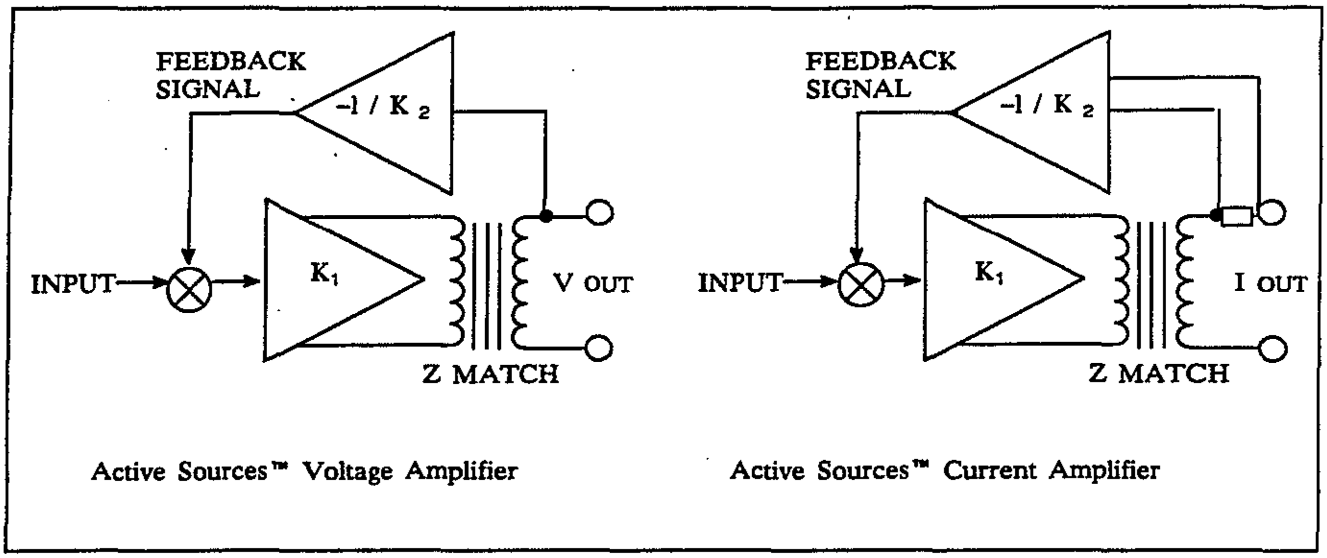


Figure 4-4. Active Sources™ Power Amplifier Configurations.

The alternate (compliance) parameter varies with the load up to the source's power capacity.

If the load exceeds the rated capacity the output signal is clipped. If an error (such as clipping) exceeding 1% in amplitude or phase shift or 2% in distortion is detected, an Error Detector sounds a beeper five times and ER appears blinking in the source's SOURCE display.

F2200 Convertible Source

The F2200 Convertible Source's Power Amplifier drives either an I-Output or a V-Output transformer, and can be switched (by relays) to provide either a current output or a voltage output. Both transformers are identical to the ones in the F2100, and provide the same ranges and power.

F2500 Convertible Source

The lower F2500 convertible source is similar to the F2200 convertible source described above. However the upper source is rated at 80 VA rather than the 105 VA of the lower source and so has lower maximum output current ranges. All other parameters are equivalent to those of other sources.

SECTION V
CALIBRATION VERIFICATION

*

The Active Sources® amplifiers in F2000 Test Instruments and Slave Sources produce highly accurate ac voltage or current test signals. The parameters of these signals are precisely specified by the digital controls and displays on a Test Instrument's control panel, and the actual analog test signals agree with the specified parameter values within the source's limits. There are no field adjustments for calibrating the actual outputs to their specified values. This section describes how to verify that the ac test signals are actually within the calibration limits.

Ambient Accuracy

F2000 Test Instruments are normally used in areas where the temperature is between 68 and 86 degrees Fahrenheit (20-30°C) and the ac power is within ±10 percent of 120 (or 240) volts. Under these conditions, and when connected to a load that does not exceed the source's range limits, F2000 ac test signals are warranted to meet the ambient accuracy specifications listed below.

Amplitude — within ±0.1% of range from 0 to 10 percent of range, and within ±0.5% of setting from 10 to 100 percent of range.

Phase Angle — within ±0.5° of the setting at 50 and 60 Hz.

Frequency — within ±0.01 Hz with the standard XTAL REF, or within ±0.005 Hz with the F2950 Precision Frequency Reference, at the base frequency.

Distortion — less than 1% total harmonic distortion at the base frequency.

TEST SETUP

Set the Test Instrument (and Slave Source) to be checked up as described in Section III, then turn the unit(s) ON. For the F2100/2200/2500 instruments check that the Instrument displays the Pon (Powerup) and WU (Warmup) messages, then indicates the correct powerup states. For the F2350 the displays are blanked until the instrument completes Warmup. If an error message appears, check the Appendix and call Doble if necessary.

Connect a load to the source to be checked, then connect the test equipment to the load, as shown for each type of test.

TEST EQUIPMENT

The test equipment and instruments listed in Table 5-1 are required to verify the calibration accuracy of an F2000 ac test signal. All items must be at least 10 times more accurate than the signal being checked and have a valid calibration sticker tracing their calibration back to National Bureau of Standards references. If the specified items are not available similar items may be substituted provided they are at least as accurate.

Since Doble's factory calibration procedure is, for the most part, twice as stringent as required, it is recommended that test equipment and instruments be an order of magnitude more accurate be used if precision calibration is required.

TABLE 5-1
TEST EQUIPMENT AND INSTRUMENTS

ITEM	MANUFACTURER AND MODEL
Differential Amplifier	Input Impedance ≥10K Ω Gain = 1 and 10, ±1% Common Mode ≥1 volt.
Differential Voltmeter, true RMS	Fluke, Model 931B
Distortion Analyzer	Hewlett-Packard, #332A
Phase Meter	Krohn-Hite, Model 6620
Precision Shunt, 0.050 Ω, 20 A	Julie, CS-IR-20
Precision Shunt, 0.020 Ω, 50 A	Julie, CS-IR-50
Precision Shunt, 0.010 Ω, 100 A	Leeds and Northrup, #4361
Precision Shunt, 0.001 Ω, 300 A	Leeds and Northrup, #4363
Voltage Source Loads:	
Resistor, 70.3 Ω, 100 W	
Resistor, 281 Ω, 100 W	
Resistor, 1125 Ω, 100 W	
Capacitor, 38 μFd	
Capacitor, 9.5 μFd	
Capacitor, 2.35 μFd	
Current Source Loads:	
Resistor, 0.105 Ω, 200 W	
Resistor, 0.154 Ω, 200 W	
Resistor, 0.571 Ω, 200 W	
Resistor, 9.89 Ω, 200 W	
High Power Current Source Loads:	
Resistor, 0.01853 Ω, 1000 W	
Resistor, 0.06812 Ω, 1000 W	
Resistor. 0.09204 Ω, 1000 W	
Resistor, 0.1800 Ω, 1000 W	
Resistor, 0.2269 Ω, 1000 W	
Resistor, 0.2925 Ω, 1000 W	
Resistor, 0.5355 Ω, 1000 W	
Resistor, 0.7800 Ω, 1000 W	
Resistor, 1.200 Ω, 1000 W	
Resistor, 2.172 Ω, 1000 W	
Resistor, 4.950 Ω, 1000 W	
Resistor, 19.95 Ω, 1000 W	
Inductor, saturating, 3 winding	custom: Electro-Core H-464 core; 0.41 mH for 26 A load = 4 turns #4 square Cu wire; 1.65 mH for 13 A load = 8 turns #8 square Cu wire; 26.4 mH for 3.25 A load = 32 turns #20 round Cu wire; 12" leads.

NOTE: Always connect a load directly to the Instrument's terminals to minimize inductive and resistive lead losses.

NOTE: All return (black) terminals are grounded internally. They are shown by solid circles in this section's diagrams.

F2100/F2200/F2500 VOLTAGE SOURCES

V Source Amplitude and Distortion

Set up the Instrument and Test Equipment as shown in Figure 5–1 below, then measure the output voltage and total harmonic distortion (THD) at 10%, 30%, and 100% of each range. All values must meet the limits in Table 5–2.

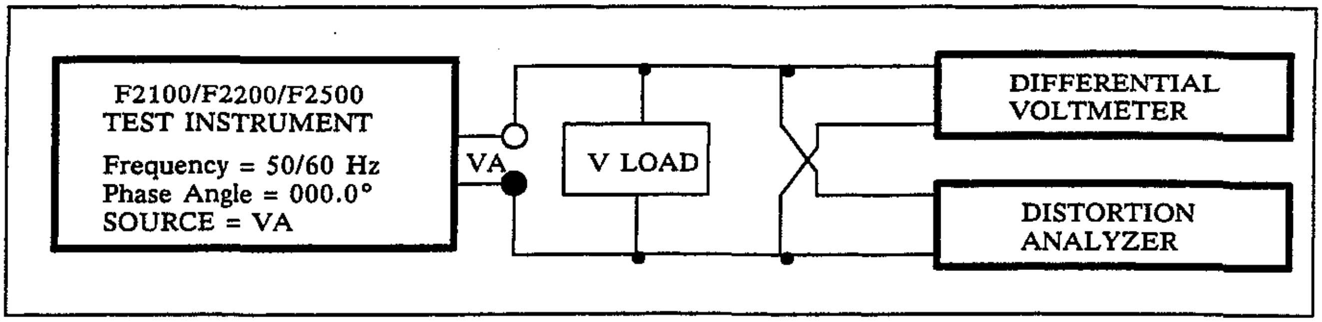


Figure 5–1. V Source Amplitude and Distortion Checks Configuration.

1. Set RANGE to 75 V and AMPLITUDE to 7.5 V, connect a 70 Ω load to the output terminals, and turn the source ON. Verify that the amplitude is within limits and the total harmonic distortion (THD) is less than 1 percent.

2. Change the amplitude to each value in Table 5–2 and verify that the amplitude and distortion are within the limits.

3. Repeat steps 1 and 2 for the 150 and 300 V ranges with the loads listed in Table 5–2 for each range.

TABLE 5–2. VOLTAGE SOURCE AMPLITUDE AND DISTORTION CHECKS.

RANGE	LOAD	VALUE	MINIMUM	MAXIMUM	MAX. THD
75 V	70.3 Ω	7.5 V	7.425 V	7.575 V	1.0 %
		37.5 V	37.31 V	37.69 V	1.0 %
		75.0 V	74.62 V	75.38 V	1.0 %
150 V	281 Ω	15.0 V	14.85 V	15.15 V	1.0 %
		75.0 V	74.62 V	75.38 V	1.0 %
		150.0 V	149.2 V	150.8 V	1.0 %
300 V	1125 Ω	30.0 V	29.70 V	30.30 V	1.0 %
		150.0 V	149.2 V	150.8 V	1.0 %
		300.0 V	298.5 V	301.5 V	1.0 %

V Source Phase Angle and Regulation

Set the Instrument and Test Equipment up as shown in Figure 5–2 on the next page; then measure the output voltage and phase angle (relative to the other source) at maximum amplitude for each range. All values must meet the limits in Table 5–3.

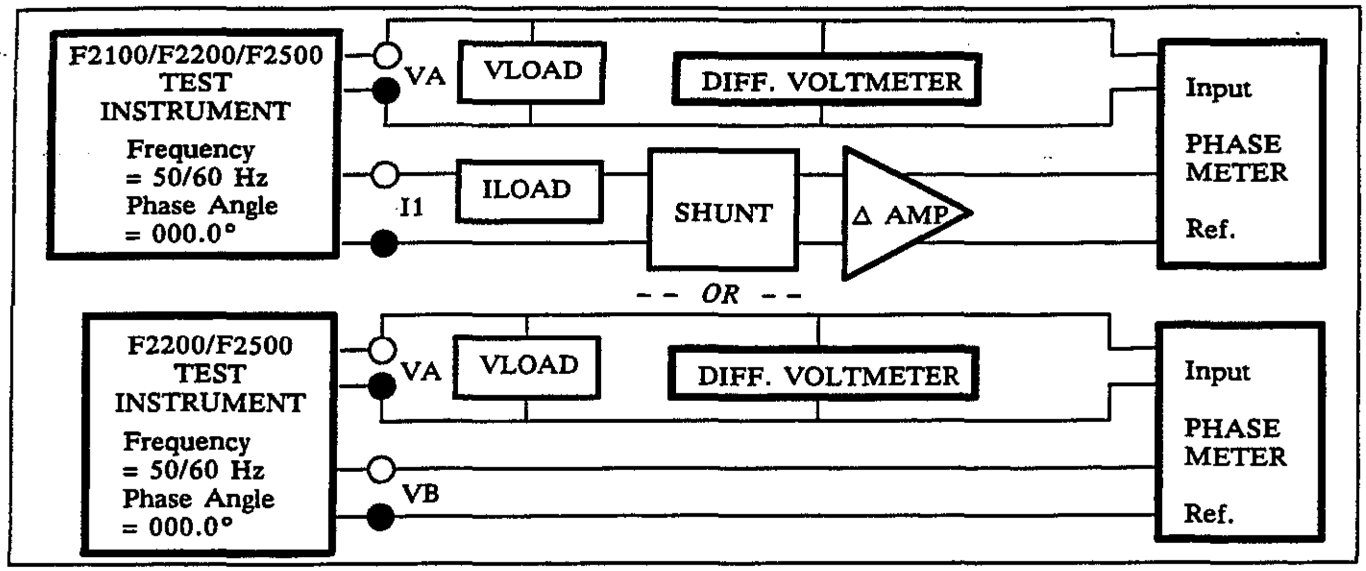


Figure 5-2. V Source Phase Angle and Regulation Checks Configuration.

1. With no load on the output of the source to be checked, turn both sources ON and verify that the output and phase angle are within the ±0.5° ambient calibration limits. Turn the sources off when finished.
2. Connect a full-range resistive load to the output of the source to be checked, then turn the sources back ON and verify that the phase angle is within limits. Turn the sources off when finished.
3. Connect a capacitive load to the output of the source to be checked, then turn the sources back ON and verify that the phase angle is within limits. Turn the sources off when finished.
4. Repeat steps 1 through 3 for the other ranges, using the loads specified in Table 5-3.

TABLE 5-3. VOLTAGE SOURCE PHASE ANGLE AND REGULATION CHECKS.

RANGE	AMPL.	LOAD	PHASE	MINIMUM	MAXIMUM
75 V	75.0 V	open	000.0	-000.5°	+000.5°
		70.3 Ω	000.0	-000.5°	+000.5°
		38 μFd	000.0	-000.5°	+000.5°
150 V	150.0 V	open	000.0	-000.5°	+000.5°
		281 Ω	000.0	-000.5°	+000.5°
		9.5 μFd	000.0	-000.5°	+000.5°
300 V	300.0 V	open	000.0	-000.5°	+000.5°
		1125 Ω	000.0	-000.5°	+000.5°
		2.35 μFd	000.0	-000.5°	+000.5°

V Source Short Circuit Protection

Set RANGE to 75 V and AMPLITUDE to 1.0 V, connect a 70 Ω load to the output terminals, turn the voltage source ON, and measure its output parameter values. Short the output terminals. The beeper should sound for 5 seconds and ER (for error) should appear in the SOURCE display. Remove the short and check that the error indications cease and the output returns to its previous values. Turn the source off when finished.

V Source Output Error Detection

Set RANGE to 150 V and AMPLITUDE to 0.00 V, connect a 70Ω load to the output terminals (this presents a load greater than the range limit), and turn the source ON. Ramp the voltage up rapidly until the beeper sounds (it stops after five seconds) and ER appears in the SOURCE 1 display. Ramp the voltage down until ER is replaced with VA, then slowly ramp it up again until the beeper sounds. Turn the source off and remove the load when finished.

F2100/F2200/F2500 CURRENT SOURCE 2 - TESTS.

I Source Amplitude and Distortion

Set the Instrument and Test Equipment up as shown in Figure 5-3 below, then measure the shunt voltage and total harmonic distortion (THD) at 10%, 30%, and 100% of each range. All values must meet the limits in Table 5-4A for F2100/F2200 and F2500 SOURCE 2 in CURRENT MODE. (See TABLE 5-4B for F2500 SOURCE 1 in CURRENT MODE.)

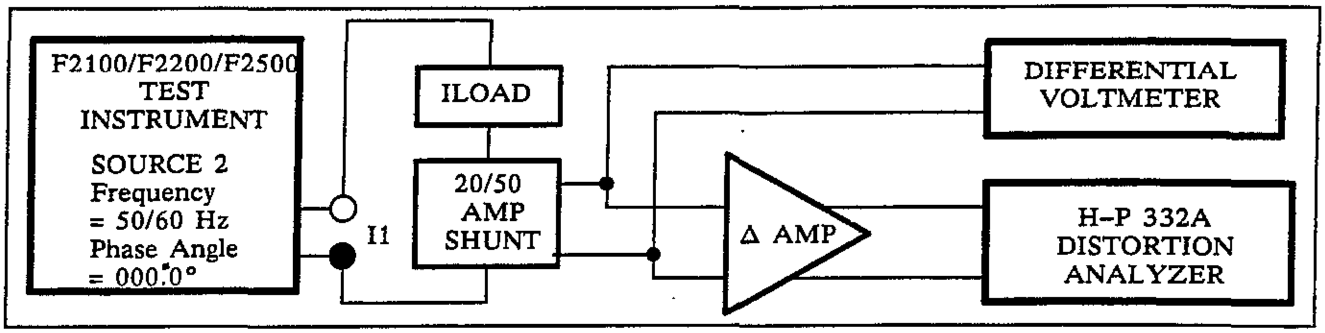


Figure 5-3A. I Source Amplitude and Distortion Checks Configuration.

1. Set RANGE to 3.25 A and AMPLITUDE to 0.320 A (10% of range), connect a full-range resistive load (9.89 Ω) and a 20 A shunt to the output terminals, turn the source ON, and verify that the amplitude is within limits shown in Table 5-4A and the total harmonic distortion (THD) is less than 1 percent.
2. Change the amplitude to the other value (30% and 100% of range) in Table 5-4A, and verify that the amplitude and distortion are within limits. Turn the source off when finished.
3. Replace the resistive load with the saturating inductive load, then turn the source back on and verify that its output is still within the limits.
4. Repeat steps 1, 2, and 3 for the 13 and 26 A ranges, with the loads listed in Table 5-4A for each range. Change to a 50 A shunt for 26 ampere checks.

TABLE 5-4A. CURRENT SOURCE AMPLITUDE AND DISTORTION CHECKS.

RANGE	LOAD	VALUE	MINIMUM	MAXIMUM	MAX. THD
3.25 A	9.89 Ω +	0.320 A	15.8 mV	16.2 mV	1.0 %
	0.050 Ω	1.600 A	79.6 mV	80.4 mV	1.0 %
	shunt	3.250 A	161.7 mV	163.3 mV	1.0 %
	inductor	3.250 A	161.7 mV	163.3 mV	1.0 %
13 A	0.571 Ω	1.30 A	64.3 mV	65.7 mV	1.0 %
	+ 0.05 Ω	6.50 A	323.3 mV	326.7 mV	1.0 %
	shunt	13.00 A	646.7 mV	653.3 mV	1.0 %
	inductor	13.00 A	646.7 mV	653.3 mV	1.0 %
26 A	0.105 Ω	2.60 A	128.7 mV	131.3 mV	1.0 %
	+ 0.05 Ω	13.00 A	646.7 mV	653.3 mV	1.0 %
	shunt				
	0.154 Ω	26.00 A	517.4 mV	522.6 mV	1.0 %
	+ 0.02 Ω				
	shunt				
	inductor	26.00 A	517.4 mV	522.6 mV	1.0 %

NOTE: see Table 5.1 for inductor details.

F2500 CURRENT SOURCE 1 - TESTS.

I Source Amplitude and Distortion

Set the Instrument and Test Equipment up as shown in Figure 5-3B below, then measure the shunt voltage and total harmonic distortion (THD) at .32A, 30%, and 100% of each range. All values must meet the limits in Table 5-4B for F2500 SOURCE 2 in CURRENT MODE.

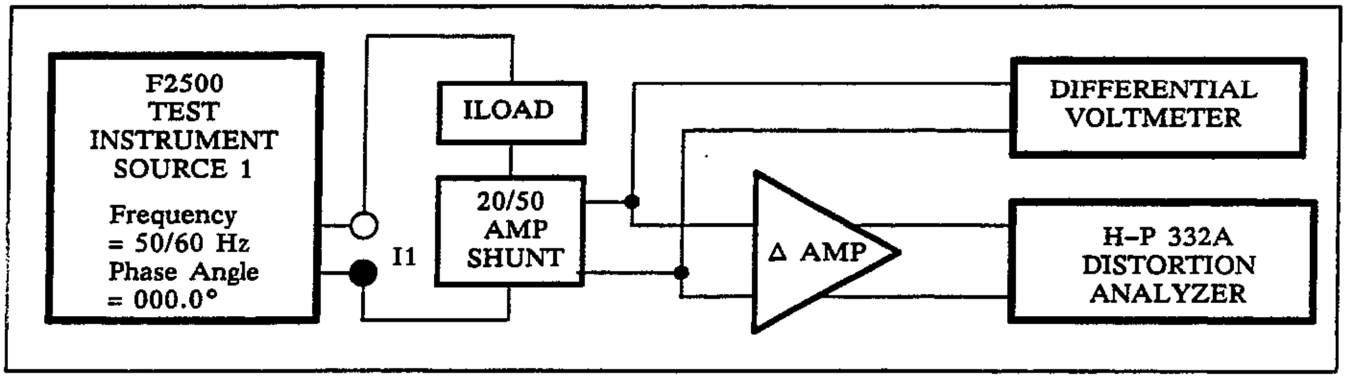


Figure 5-3B. I Source Amplitude and Distortion Checks Configuration.

1. Set RANGE to 2.25 A and AMPLITUDE to 0.320 A, connect a full-range resistive load (14.3 Ω) and a 20 A shunt to the output terminals, turn the source ON, and verify that the amplitude is within limits shown in table 5-4B and the total harmonic distortion (THD) is less than 1 percent.
2. Change the amplitude to the other value (30% and 100% of range) in Table 5-4B, and verify that the amplitude and distortion are within limits. Turn the source off when finished.
3. Replace the resistive load with the saturating inductive load, then turn the source back on and verify that its output is still within the limits.
4. Repeat steps 1, 2, and 3 for the 9 and 18 A ranges, with the loads listed in Table 5-4B for each range.

TABLE 5-4B. CURRENT SOURCE AMPLITUDE AND DISTORTION CHECKS.

RANGE	LOAD	VALUE	MINIMUM	MAXIMUM	MAX. THD
2.25 A	14.3 Ω +	0.320 A	15.7 mV	16.3 mV	1.0 %
	0.050 Ω	1.1 A	54.7 mV	55.3 mV	1.0 %
	shunt	2.25 A	112.0 mV	113.1 mV	1.0 %
	inductor	2.25 A	112.0 mV	113.1 mV	1.0 %
9 A	0.897 Ω	1.30 A	64.3 mV	65.7 mV	1.0 %
	+ 0.05 Ω	4.5 A	224.0 mV	226.0 mV	1.0 %
	shunt	9.0 A	448.0 mV	452.0 mV	1.0 %
	inductor	9.0 A	448.0 mV	452.0 mV	1.0 %
18 A	0.174 Ω	2.60 A	128.7 mV	131.3 mV	1.0 %
	+ 0.05 Ω	9.0 A	448.0 mV	452.0 mV	1.0 %
	shunt				
	inductor	.18 A	895.0 mV	905.0 mV	1.0 %
		.18 A	895.0 mV	905.0 mV	1.0 %

NOTE: see Table 5.1 for inductor details.

F2100/F2200/F2500 SOURCE 2 – TESTS.

I Source Phase Angle and Regulation

Set the Instrument and Test Equipment up as shown in Figure 5–4A below, then measure the shunt voltage and phase angle (relative to VA) at maximum output on each range. All values must meet the limits in Table 5–5A. (See TABLE 5–5B for F2500 SOURCE 1 Tests.)

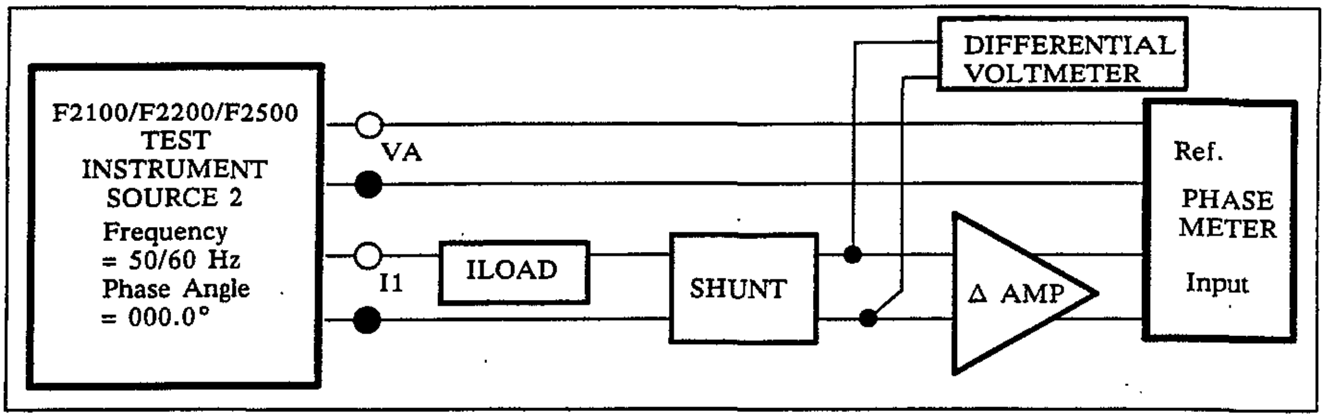


Figure 5–4A. I Source Phase Angle and Regulation Checks Configuration.

1. Set the RANGE to 3.25 A and short the terminals of the load, then turn the source ON and verify that the output and phase angle are within the calibration limits shown in Table 5–5A. Turn the source off when finished.
2. Connect a full–range resistive load (9.89 Ω) into the circuit as I LOAD, then turn the source ON and verify that the output and phase angle are within the calibration limits shown in Table 5–5A. Turn the source off when finished.
3. Connect a saturating inductive load into the circuit as I LOAD, then turn the source ON and verify that the output and phase angle are within the calibration limits shown in Table 5–5A. Turn the source off when finished.
4. Repeat steps 1 through 3 for the 13 A and 26 A ranges.

TABLE 5–5A. CURRENT SOURCE PHASE ANGLE AND REGULATION CHECKS.

RANGE	AMPL.	LOAD	PHASE	MINIMUM	MAXIMUM
3.25 A	3.250 A	short	000.0	–000.5°	+000.5°
		9.89 Ω	000.0	–000.5°	+000.5°
		inductor	000.0	–000.5°	+000.5°
13 A	13.00 A	short	000.0	–000.5°	+000.5°
		0.571 Ω	000.0	–000.5°	+000.5°
		inductor	000.0	–000.5°	+000.5°
26 A	26.00 A	short	000.0	–000.5°	+000.5°
		0.154 Ω	000.0	–000.5°	+000.5°
		inductor	000.0	–000.5°	+000.5°

I Source Open Circuit Protection and Output Error Detection

Set the SOURCE 2 range to 3.25 A and its amplitude to 1.00 A, open its output terminals; and turn the source ON. Check that the beeper sounds for 5 seconds and ER appears in the SOURCE 2 display. Turn the source off when finished.

WARNING: DANGEROUS AND POTENTIALLY LETHAL VOLTAGES WILL EXIST ACROSS THE OPEN CIRCUITED OUTPUT TERMINALS DURING THIS TEST

F2500 CURRENT SOURCE 1 - TESTS.

I Source Phase Angle and Regulation

Set the Instrument and Test Equipment up as shown in Figure 5-4B below, then measure the shunt voltage and phase angle (relative to VA) at maximum output on each range. All values must meet the limits in Table 5-5B.

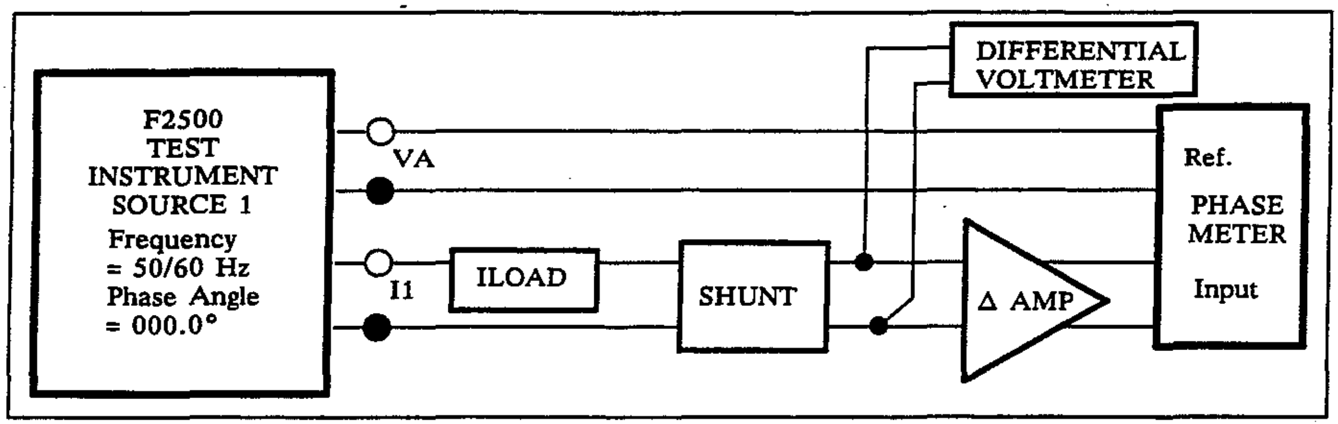


Figure 5-4B. I Source Phase Angle and Regulation Checks Configuration.

1. Set the RANGE to 2.25 A and short the terminals of the load, then turn the source ON and verify that the output and phase angle are within the calibration limits shown in Table 5-5B. Turn the source off when finished.
2. Connect a full-range resistive load (14.3 Ω) into the circuit as I LOAD, then turn the source ON and verify that the output and phase angle are within the calibration limits shown in Table 5-5B. Turn the source off when finished.
3. Connect a saturating inductive load into the circuit as I LOAD, then turn the source ON and verify that the output and phase angle are within the calibration limits shown in Table 5-5B. Turn the source off when finished.
4. Repeat steps 1 through 3 for the 9 A and 18 A ranges.

TABLE 5-5B. CURRENT SOURCE PHASE ANGLE AND REGULATION CHECKS.

RANGE	AMPL.	LOAD	PHASE	MINIMUM	MAXIMUM
2.25 A	2.250 A	short	000.0	-000.5°	+000.5°
		9.89 Ω	000.0	-000.5°	+000.5°
		inductor	000.0	-000.5°	+000.5°
9 A	9.00 A	short	000.0	-000.5°	+000.5°
		0.897 Ω	000.0	-000.5°	+000.5°
		inductor	000.0	-000.5°	+000.5°
18 A	18.00 A	short	000.0	-000.5°	+000.5°
		0.174 Ω	000.0	-000.5°	+000.5°
		inductor	000.0	-000.5°	+000.5°

I Source Open Circuit Protection and Output Error Detection

Set the SOURCE 1 range to 2.25 A and its amplitude to 1.00 A, open its output terminals, and turn the source ON. Check that the beeper sounds for 5 seconds and ER appears in the SOURCE 1 display. Turn the source off when finished.

WARNING: DANGEROUS AND POTENTIALLY LETHAL VOLTAGES WILL EXIST ACROSS THE OPEN CIRCUITED OUTPUT TERMINALS DURING THIS TEST

HIGH POWER CURRENT SOURCES

H/L Source Amplitude and Distortion

Set the Instrument and Test Equipment up as shown in the appropriate sections of Figure 5-5 or 5-6, then measure the shunt voltage and total harmonic distortion (THD) at 10%, 50%, and 100% of each range. All values must meet the limits in Table 5-6 for the F2300 and F2350 or in Table 5-7 for the F2300A.

1. Set the source to the High Power (HI) mode and the range to 5 A, connect the 19.95 Ω 1000 W load and 0.05 Ω 20 A shunt to the output terminals, set the amplitude to 0.500 A, and turn the source ON. Verify that the amplitude is within limits and the total harmonic distortion (THD) is less than 1 percent.
2. Change the amplitude to each value in Table 5-6 for an F2300 or F2350, or Table 5-7 for an F2300A, and verify that the amplitude and distortion are within the limits listed.
3. Repeat steps 1 and 2 for all the other ranges with the loads listed for each range in the appropriate table.

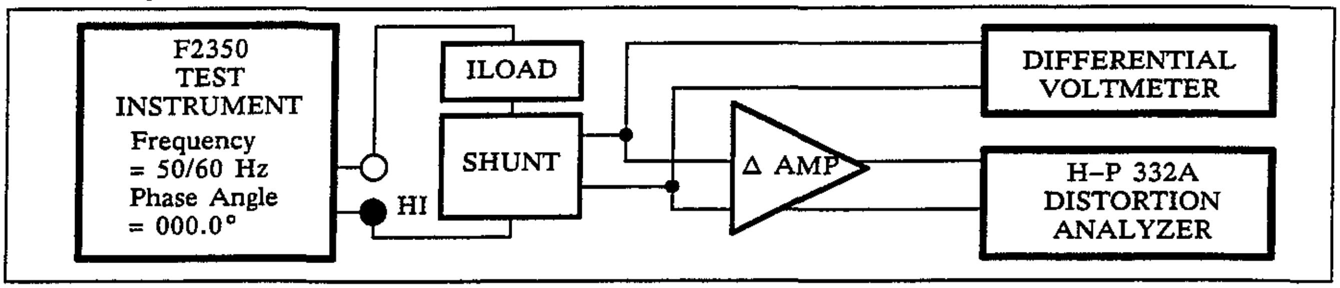


Figure 5-5. F2350 Amplitude and Distortion Checks Configurations.

TABLE 5-6. F2300/F2350 HIGH POWER CURRENT SOURCES AMPLITUDE AND DISTORTION CHECK VALUES.

RANGE	LOAD	VALUE	MINIMUM	MAXIMUM	MAX. THD
5.000 A	19.95 Ω +	0.500 A	24.7 mV	25.3 mV	1.0 %
	0.050 Ω	2.500 A	124.4 mV	125.6 mV	1.0 %
	shunt	5.000 A	248.7 mV	251.3 mV	1.0 %
10.00 A	4.950 Ω +	1.00 A	49.5 mV	50.5 mV	1.0 %
	0.050 Ω	5.00 A	248.7 mV	251.3 mV	1.0 %
	shunt	10.00 A	497.5 mV	502.5 mV	1.0 %
15.00 A	2.172 Ω +	1.5 A	74.2 mV	75.8 mV	1.0 %
	0.050 Ω	7.50 A	373.1 mV	376.9 mV	1.0 %
	shunt	15.00 A	746.2 mV	753.8 mV	1.0 %
20.00 A	1.200 Ω +	2.00 A	99.0 mV	101.0 mV	1.0 %
	0.050 Ω	10.00 A	497.5 mV	502.5 mV	1.0 %
	shunt	20.00 A	995.0 mV	1005.0 mV	1.0 %
25.00 A	0.780 Ω +	2.50 A	49.5 mV	50.5 mV	1.0 %
	0.020 Ω	12.50 A	248.7 mV	251.3 mV	1.0 %
	shunt	25.00 A	497.5 mV	502.5 mV	1.0 %
30.00 A	0.535 Ω +	3.00 A	59.4 mV	60.6 mV	1.0 %
	0.020 Ω	15.00 A	298.5 mV	301.5 mV	1.0 %
	shunt	30.00 A	597.0 mV	603.0 mV	1.0 %
40.00 A	0.292 Ω +	4.00 A	79.20 mV	80.8 mV	1.0 %
	0.020 Ω	20.00 A	398.0 mV	402.0 mV	1.0 %
	shunt	40.00 A	796.0 mV	804.0 mV	1.0 %
50.00 A	0.1800 Ω +	5.00 A	99.0 mV	101.0 mV	1.0 %
	0.0200 Ω	25.00 A	497.5 mV	502.5 mV	1.0 %
	shunt	50.00 A	995.0 mV	1005.0 mV	1.0 %
80.00 A	0.0681 Ω +	8.00 A	79.2 mV	80.8 mV	1.0 %
	0.0100 Ω	40.00 A	398.0 mV	402.0 mV	1.0 %
	shunt	80.00 A	796.0 mV	804.0 mV	1.0 %
160.0 A	0.0185 Ω +	16.00 A	15.8 mV	16.2 mV	1.0 %
	0.0010 Ω	80.00 A	79.6 mV	80.4 mV	1.0 %
	shunt	100.0 A	99.5 mV	100.5 mV	1.0 %

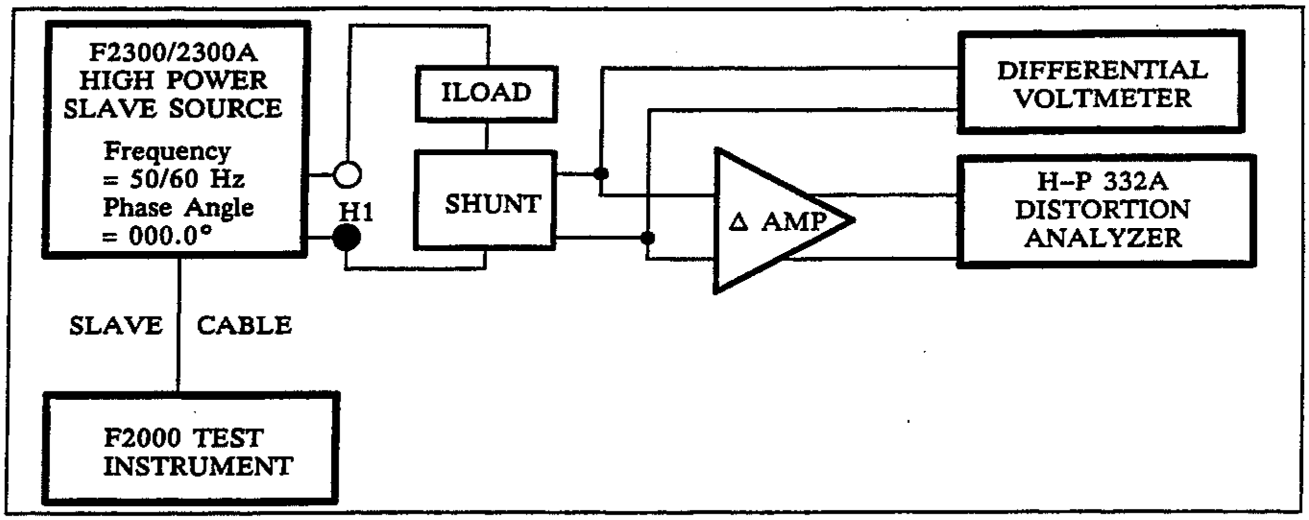


Figure 5-6. F2300/F2300A Amplitude and Distortion Checks Configurations.

TABLE 5-7. F2300A HIGH POWER CURRENT SOURCE AMPLITUDE AND DISTORTION CHECK VALUES.

RANGE	LOAD	VALUE	MINIMUM	MAXIMUM	MAX. THD
5.00 A	19.95 Ω +	0.500 A	24.7 mV	25.3 mV	1.0 %
	0.050 Ω	2.500 A	124.4 mV	125.6 mV	1.0 %
	shunt	5.000 A	248.7 mV	251.3 mV	1.0 %
15.00 A	2.17 Ω +	1.50 A	74.2 mV	75.8 mV	1.0 %
	0.050 Ω	7.50 A	373.1 mV	376.9 mV	1.0 %
	shunt	15.00 A	746.2 mV	753.8 mV	1.0 %
30.00 A	0.535 Ω +	3.00 A	59.4 mV	60.6 mV	1.0 %
	0.020 Ω	15.00 A	298.5 mV	301.5 mV	1.0 %
	shunt	30.00 A	597.0 mV	603.0 mV	1.0 %
45.00 A	0.227 Ω +	4.50 A	89.1 mV	90.9 mV	1.0 %
	0.020 Ω	22.50 A	447.7 mV	452.3 mV	1.0 %
	shunt	45.00 A	895.5 mV	904.5 mV	1.0 %
70.00 A	0.092 Ω +	7.00 A	69.3 mV	70.7 mV	1.0 %
	0.010 Ω	35.00 A	348.2 mV	351.8 mV	1.0 %
	shunt	70.00 A	696.5 mV	703.5 mV	1.0 %
160.0 A	0.0185 Ω	16.00 A	15.8 mV	16.2 mV	1.0 %
	+ 0.001 Ω	80.00 A	79.6 mV	80.4 mV	1.0 %
	shunt	100.0 A	99.5 mV	100.5 mV	1.0 %

H/L Source Phase Angle and Regulation

Set both Instruments and the Test Equipment up as shown in Figure 5–7 below, then measure the shunt voltage and phase angle for the 5 A, 30 A, and 160 A ranges (relative to the F2000 Test Instrument). All values must meet the limits in Table 5–8.

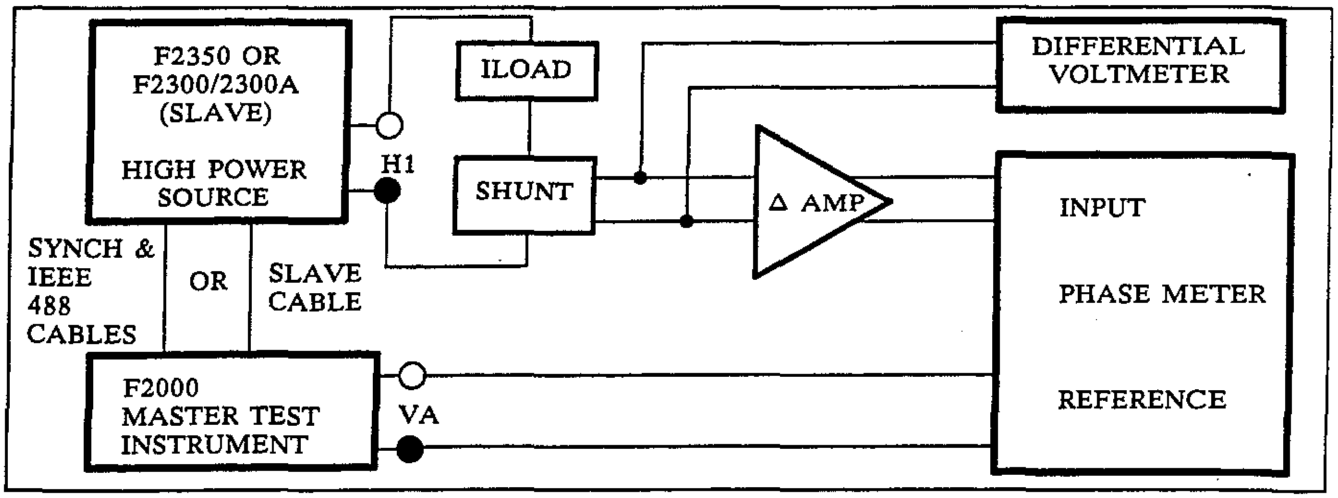


Figure 5–7. H/L Current Source Phase Angle and Regulation Checks.

1. Set the SOURCE to H1, the RANGE to 5 A, and the AMPLITUDE to 5.000 A. Short the load terminals, then turn the source ON and verify that its amplitude and phase angle are within the calibration limits. Turn the source off when finished.
2. Connect a full–range resistive load into the circuit as I LOAD, then turn the source ON and verify that the phase angle is within the limits. Turn the source off when finished.
3. Connect a saturating inductive load into the circuit as I LOAD, then turn the source ON and verify that the phase angle is within the limits. Turn the source off when finished.
4. Repeat steps 1 through 3 for the 30 A and 160 A ranges.

TABLE 5–8. H/L CURRENT SOURCE PHASE ANGLE AND REGULATION CHECKS.

RANGE	AMPLTD.	LOAD	PHASE	MINIMUM	MAXIMUM
5 A	5.000 A	short (shunt only)	000.0°	–000.5°	+000.5°
		19.95 Ω + 0.050 Ω 20 A shunt	000.0°	–000.5°	+000.5°
30 A	30.00 A	short (shunt only)	000.0°	–000.5°	+000.5°
		0.544 Ω + 0.020 Ω 50 A shunt	000.0°	–000.5°	+000.5°
160 A	160.0 A	short (shunt only)	000.0°	–000.5°	+000.5°
		0.0185 Ω + 0.001 Ω 300 A shunt	000.0°	–000.5°	+000.5°

H/L Source Output Error Detection and Open Circuit Protection

Set the SOURCE to L1, RANGE to 5 A, and AMPLITUDE to 1.000 A. Open the output terminals and turn the source ON. Check that the beeper sounds for 5 seconds and ER appears in the SOURCE display. Turn the source off when finished.

WARNING: DANGEROUS AND POTENTIALLY LETHAL VOLTAGES WILL EXIST ACROSS THE OPEN CIRCUITED OUTPUT TERMINALS DURING THIS TEST

SECTION VI
SPECIFICATIONS

*

SYSTEM CONTROLS

RAMP/SET .... SET: sets each amplitude/phase angle digit individually;

RAMP: increments/decrements amplitude/phase angle value continuously. (at different rates).

SYSTEM OUTPUT .... turns every source that has been 'Enabled' on (lighted) or off (dark).

ZERO X .... SOURCE (amplitude changes occur at each source's zero crossing);

SYSTEM (amplitude changes occur simultaneously at system's reference).

FREQUENCY .... LINE SYNCH (tracks power line); XTAL (crystal reference).

FREQUENCY

Base Frequency .... 50 or 60 Hertz, crystal or line synchronized.

Selectable Frequencies ...... 2nd through 10th harmonic of BASE FREQ.

Accuracy .... standard crystal = ±0.01%; precision crystal = ±0.0005%.

Line Synchronization .... signal frequency tracks line frequency for variations of ± 1 Hz on nominal base frequency (50 or 60 Hz).

Variable Frequency Options . F2010 Minicontroller, ProTesT II. 25.00 to 99.99 and 100.0 to 600.0 Hz.

Resolution .... 0.01 Hz from 25.00 to 99.99 Hz; 0.1 Hz from 100.0 Hz to 600.0 Hz.

SOURCE CONTROLS

SOURCE 1 .... F2100/F2200: selects voltage source designation;

F2350: left selects High or Low Power Mode, right selects source designation.

F2500: left selects voltage or current mode, right selects source designation.

SOURCE 2 .... F2100: selects current source designation;

F2200/F2500: left selects voltage or current mode, right selects source designation.

Value Switches .... up increments, down decrements;

individually (SET mode) or continuously (RAMP mode).

ON/ENABLE .... ON: turns source on or off individually.

ENABLE: enables/disables on/off control by SYSTEM OUTPUT.

HERTZ/RANGE .... right: cyclicly selects ranges and AutoRange mode;

left: selects 1st through 10th harmonic of base frequency.

OUTPUTS

AC Voltage (F2100/F2200/F2500)

Designations	standard: VA, VB, VC; VM (F2825 option). extended: VR, VS, VT, VR, VY, VB.
Ranges	three: 75/150/300 volts @ 80 VA. 75 volts: 0.01–75.00 V rms to 1.066 A rms (≥70.31 Ω) 150 volts: 0.1–150.0 V rms to 0.533 A rms (≥281.2 Ω) 300 volts: 0.1–300.0 V rms to 0.266 A rms (≥1.125K Ω)
Accuracy	10–100% of range: ±0.25% of setting typical, ±0.5% of setting maximum @ 20–30°C; ±1% of setting absolute maximum @ 0–50°C. 0–10% of range: ±0.1% of range.
Resolution	75 V range = 0.01 V, 150 and 300 V ranges = 0.1 V
Load Power	80 VA continuous at maximum range at 50 or 60 Hz.
Load Power Factor	0–1, leading or lagging.
Deratings	power and voltage decreases linearly to 50% of specifications from 45 down to 25 Hz, and for input voltages less that 105/210 V.
Total Harmonic Distortion	1% typical; 2% maximum, at 50 or 60 Hz.
Phase Angle	0 to ±359.9°.
Phase Accuracy	±0.2° typical; ±0.5° maximum, @ 50/60 Hz.
Error Detection	>1% amplitude and phase, >2% distortion audible beeper and blinking ER message.
Output Protection	short circuit proof, current limiting.
High Voltage Alarm	blinking red indicator when output ≥20 V.

DC Voltage (F2410)

Designation (in Master's SOURCE)	DV.
Ranges (in Master's RANGE)	three: 75/150/300 volts @ 80 W.
Amplitude (in Master's AMPL)	75 volts: 7.5–75.00 V (≥70.31 Ω) 150 volts: 15–150.0 V (≥281.2 Ω) 300 volts: 30–300.0 V (≥1.125K Ω)
Accuracy	±1% of setting and ±1 V.
Resolution	75 V range = 0.01 V, 150 and 300 V ranges = 0.1 V.
Load Power	80 W continuous at maximum range.
Ripple	≤5% of range peak-to-peak @ maximum load.

AC Current (F2100/F2200/F2300/F2300A/F2350/F2500)

Designations	F2100/F2200/F2500:	standard = I1, I2, I3, IP; IM (F2825 option); extended = IR, IS, IT; IR, IY, IB.

	F2300/F2300A/F2350:	standard: low power = L1, L2, L3; LM (2825 option);
		high power=H1, H2, H3; HM (2825 option).
		extended: low power = LR, LS, LT; LR, LY, LB;
		high power=HR, HS, HT; HR, HY, HB.

OUTPUTS *(CONTINUED)*

AC Current (F2100/F2200/F2300/F2300A/F2350/F2500) (continued)

Output Ranges .... **F2100/F2200/F2500(SOURCE 2)**: three; 3.25/13/26 A @ 105 VA.
26 amperes: 0.01–26 A rms to 4 V rms (≤0.155 Ω)
13 amperes: 0.01–13 A rms to 8 V rms (≤0.62 Ω)
3.25 amperes: 0.001–3.25 A rms to 32 V rms (≤9.94 Ω)

F2500(SOURCE 1): three; 2.25/9/18 A @ 72 VA
18 amperes: 0.01 – 18 A rms to 4 V (≤ 0.224 Ω)
9 amperes: 0.01 – 9 A rms to 8 V (≤ 0.897 Ω)
2.25 amperes: 0.001 – 2.25 A rms to 32.3 V (≤ 14.3 Ω)

F2350: ten; 5/10/15/20/25/30/40/50/80/160 A @ 300/500 VA.
5 amperes: 0.001–5 A rms to 100 V rms (≤20 Ω)
10 amperes: 0.01–10 A rms to 50 V rms (≤ 5 Ω)
15 amperes: 0.01–15 A rms to 33.3 V rms (≤ 2.22 Ω)
20 amperes: 0.01–20 A rms to 25 V rms (≤ 1.25 Ω)
25 amperes: 0.01–25 A rms to 20 V rms (≤ 0.800 Ω)
30 amperes: 0.01–30 A rms to 16.67 V rms (≤ 0.555 Ω)
40 amperes: 0.01–40 A rms at 12.5 V rms (0.313 Ω)
50 amperes: 0.01–50 A rms to 10 V rms (≤ 0.200 Ω)
80 amperes: 0.1–80 A rms to 6.25 V rms (≤ 0.078 Ω)
160 amperes: 0.1–160 A rms to 3.125 V rms (≤ 0.0195 Ω)

F2300: ten; same as F2350.

F2300A: six; 5/15/30/45/70/160 A @ 300/500 VA.
5 amperes: 0.01–5 A rms to 100 V rms (≤20 Ω)
15 amperes: 0.01–15 A rms to 33.3 V rms (≤ 2.22 Ω)
30 amperes: 0.01–30 A rms to 16.67 V rms (≤ 0.555 Ω)
45 amperes: 0.01–45 A rms at 11.11 V rms (0.247 Ω)
70 amperes: 0.1–80 A rms to 7.14 V rms (≤ 0.102 Ω)
160 amperes: 0.1–160 A rms to 3.125 V rms (≤ 0.0195 Ω)

Accuracy .... 10–100% of range: ±0.25% of setting typical, ±0.5% of setting maximum @ 20–30°C;
±1% of setting absolute maximum @ 0–50°C.
0–10% of range: ±0.1% of range.

Resolution .... **SRC 2 F2500/F2100/2200**: 3.25 A range = 0.001 A, 13 A and 26 A ranges = 0.01 A.

F2500 SOURCE 1: 2.25 A range = 0.001 A, 9 A and 18 A ranges = 0.01 A.

F2300/2350: 5 A range = 0.001 A, 10/15/20/25/30/40/50 A ranges = 0.01A; 80/160 ranges = 0.1 A.

F2300A: 5/15/30/45 A ranges = 0.01 A, 70/160 A ranges = 0.1 A.

OUTPUTS *(CONTINUED)*

AC Current (F2100/F2200/F2300/F2300A/F2350) - *(continued)*

Load Power .... **F2500 SRC 2/F2100/2200:** ≤105 VA @ 50/60 Hz.
F2500 SRC 1: ≤72 VA @ 50/60 Hz.
F2300/2300A/2350: ≤300/500 VA @ 50/60 Hz, ≤2100 VA peak inductive load.

Load Power Factor .... 0 to 1, leading or lagging. DC return required for capacitive loads.

Thermal Management ...... **F2300/F2300A/F2350:** 1 minute maximum on time @ 100–160 A, followed by equal time off.

Deratings .... power and compliance voltage decreases linearly to 50% of specifications from 45 to 25 Hz, and for input voltages less than 105/210 V.

Total Harmonic Distortion .... 1% typical, 2% maximum, at 50/60 Hz.

Phase Angle .... 0 to ±359.9 degrees.

Phase Accuracy .... ±0.2° typical, ±0.5° maximum, @ 50/60 Hz.

Error Detection .... >1% amplitude and phase, >2% distortion. Audible beeper and blinking ER message.

Ground Fault Detection ..... **F2300/F2300A/F2350**: automatic shutdown, beeper, GF message.

Overtemperature Protection .. **F2300/F2300A/F2350:** automatic shutdown and OT message.

Output Protection .... open circuit proof.

High Voltage Alarm .... blinking red indicator when output >20 V.

Parallel Mode .... IP designation.
System MASTER's source displays total amplitude and phase angle; controls amplitude, phase, and on/off state of all IP sources.

Slave High Current Source .. **F2300 and F2300A.**
MASTER's source displays and controls amplitude, phase, frequency, and on/off state.

DC Current (F2410)

Designation (in Master's SOURCE) ... DI.

Range (in Master's SOURCE) .... 0–3.25 amperes. (0–5.0 with F2350)

Accuracy .... ±1% of setting ±5 mA.

Resolution .... 1 mA.

Compliance Voltage .... ≥18.5 V.

Load Power .... 60 W.

Ripple .... ≤10% of setting peak–to–peak and 1% of range @ maximum load.

DC Power (F2410)

Designation (via ProTesT) .... BAT.

Output voltage .... 0, 48, 125, 250 volts.

Maximum Current .... 1.3 A @ 48 V/0.5 A @ 125 V/0.25 A @ 250 V.

Power .... 62.5 W.

DIGITAL TIMER

Ranges	0–999.99 seconds or milliseconds, automatically changes @ 1000 milliseconds. 0–999.99 cycles at system nominal base frequency of 50/60 Hz.
Display	5 decimal digit, 0.3–inch LED indicators.
Accuracy	± 0.01% of reading *and* ± 1 L.S.D.
Timer Start	Source 1 or Source 2: off–to–on/on–to–off
Timer Modes	STOP (for timing) — enabled sources turn off when timer stops. SENSE (for real–time monitoring) PULSE (for measuring contact or voltage pulse duration) START (use with phase–interface for automatic synchronizer testing)
Sense/Stop Signals	AC/DC voltages from 1–300 Dry contact: 30 V–dc open circuit; 100 mA–dc closed circuit to minimize errors due to contact film.
Sense/Stop Conditions	Voltages–off–to–on/on–to–off, or PULSE. Contacts–open–to–close/close–to–open, or PULSE.
Sense/Stop Indicators	Displays "SENSE", and sounds an audible tone.
AutoSense	Sense input interacts with RAMP mode to stop ramp automatically when Sense/Stop signal detected. This allows automatic determination of Reach/MTA/Pickup/Dropout.

PHYSICAL

Size	F2500/F2100/F2200/F2300/F2350: 9.5 x 19.75 x 22 in (24 x 50 x 55.8 cm). F2300A: 14 x 21.5 x 15.4 in (35.6 x 54.6 x 39.1 cm). F2410: 6.5 x 19.75 x 7.5 in (16.5 x 50 x 19 cm).
Weight	F2100 = 52 lbs/24 Kg. F2200 = 58 lbs/26.5 Kg. F2300 = 65 lbs/29.5 Kg. F2300A = 68 lbs/31 Kg. F2350 = 71 lbs/32 Kg. F2410 = 23 lbs/10.5 Kg. F2500 = 63 lbs/28.5 Kg.
Case	molded high–impact ABS plastic.
Temperature	operating = 0 to 50°C; storage = –25 to +70°C.
Humidity	≤95% relative humidity, non–condensing.
Vibration	National Safe Transit Association specification #1A.
Voltage	95–132 V, 60 Hz; or 190–264 V, 50 Hz. Output power decreased below 105/210 V.
Current	F2100/F2200/F2500 = 10 A maximum; F2300/F2300A/F2350 = 20 A maximum; F2410 = 5.0 A maximum.

EXTERNAL INTERFACE CONNECTIONS

IEEE-488	General Purpose Instrument Bus (GPIB) provides high speed communication link with other F2000 Test Instruments.
RS232	provides RS-232C serial communications with an external computer for remote control.
D232	Doble serial communication port for the F2010 Minicontroller.
SYNC	provides clock and reference pulses from System MASTER to synchronize frequency and control of SLAVES.
F2410	provides communication between Master F2000 and F2410 Slave DC Test Source.
F2300	provides communication between Master F2000 and F2300/F2300A Slave High Power Current Source.
FDF (optional)	provides synchronizing clock pulses from the FDF Dynamic Frequency Source.
PHASE INTF (optional)	provides zero crossing pulses to the FDF Dynamic Frequency Source.
F3 INTF (optional)	provides a synchronizing signal from an F3 3-ϕ Test System's VA or VC/I1 source.
AC POWER	receptacle for line power.

INTERNAL OPTIONS

F2810 Fault Rotate	performs a 120° Δ or Y fault rotation.
F2820 Δ Value/Δ Time	provides rate-of-change capability for amplitude/phase angle/frequency, used by the F2010 Minicontroller.
F2825 Multiple Sources	allows up to 3 sources to be controlled simultaneously by the F2010 Minicontroller.
F2835 Precision Phase Interface	±0.1°/0.25°/0.5°/1° zero crossing detection for one F2100 source, used with the FDF Dynamic Frequency Source.
F2850 Precision Frequency Reference	±0.0005%.
F2910 Protest II Starter Kit	Compatible with Compaq, IBM PC, IBMXT computers. Provides the communications link to the F2000 microcomputer and internal IEEE 488/RS232 remote control interfaces for using ProTesTPLANs™ with F2100, F2200, F2500, and F2350.

APPENDIX A
ERROR MESSAGES

*

The F2000 Test Instruments are controlled by a sophisticated software system in their microcomputers. The F2000 Software System, besides controlling all communications that directs the unit's (and any Slave's) operations, checks all operations for any errors. If an error is discovered it halts the operation in process and displays a message that identifies the problem.

NETWORK ERROR MESSAGES

A Network Error occurs if a problem is detected on the IEEE-488 Bus or SYNCH Cable. The instrument that first detects the problem stops and displays an error code in its TIME display, and halts all the other Instruments, which then display nEt in their TIME displays. The error code indicates the cause of the system crash.

To recover from a network error, press any control on the front panel of every unit. All Instruments will go to the Power On state (show Pon in their TIME display) and, when they are all ready, become active again.

Code	Message	Description
400x	RS-232 communications error.	Faulty cable connection or failure of the Host Computer or Minicontroller.
600x	IEEE-488 communications error.	Specific error identified by x.
8001	Master already present.	SYNC Cable attached without the IEEE-488 Bus, or Master/Slave transfer has taken too long.
8002	No Master for Slave.	SYNC Cable removed from an operating unit or IEEE-488 bus is attached without a SYNC Cable when powered up.
8003	Invalid network.	Multiple instruments not powered up properly, network addressing wrong.
A00x	Message format/overrun error.	Type indicated by x. May be caused by failure of ProTesT, Host Computer, or MiniController.
nEt	Network error.	Appears on all other networked units when any unit detects an error or is turned off.

INTERNAL ERROR MESSAGES

Internal Errors may occur due to a hardware or software malfunction. These halt the Instrument and display an error code in its TIME display similarly to Network Errors. Recovery can be attempted in the same way. Internal Errors usually require that the unit be serviced. When reporting problems to Doble, please record all values shown in the error display.

Code	Message	Description
0001	Watchdog Reset.	Software in an infinite loop, or attempted an operation that takes too much time.
100x	Operating system error.	Specific error identified by x.
200x	Timer mode error.	Specific error identified by x.
300X	Memory failure. (Shown only on LED's on the CPU card).	RAM chip not inserted properly on the CPU or Waveform board, CPU or Waveform board not seated properly, or Waveform board missing.
500x	Unexpected interrupt.	Specific error identified by x.
9000	Amplifier ID error.	No amplifier detected during initialization.
BUS	Bus timeout.	Missing board or software error.
B00x	Software failure.	Specific error identified by x.
C00x	Software failure.	Specific error shown by x.
D00x	Software failure.	Specific error shown by x.
E00x	Software failure.	Specific error shown by x.
Fxxx	Software failure.	Specific error shown by x.

SOURCE ERROR MESSAGES

Source Errors can occur during normal operations for a variety of reasons. When then do the beeper sounds for 5 seconds, a 2–character error code flashes in the source's SOURCE display, and the source may be turned off depending on the type of error. Some of the more common Source Errors and responses include:

Code	Message	Description
ER	Output error.	Source cannot drive load at specified amplitude. Beeps for 5 seconds, message flashes as long as source stays on.
GF	Ground Fault. (F2300/2300A/F2350 only.)	Beeps & flashes for 5 seconds, high–power source turned off. Check that the unit has the same earth/green ground as the instrument it is connected to. Check that the current is returning through the return terminal (not the chassis ground). Check that the F2300/F2350 binding posts are not overloaded (>30 A).
OT	Overtemperature. (F2300/2300A/F2350).	Beeps and flashes for 5 seconds, high–power source is turned off.
PE	Position Error (F2410 only).	Beeps and flashes for 5 seconds. Unit must be horizontal on bottom or back.
PS	Power supply error. (F2100/F2200 only).	Power supply or amplifier cannot drive excessive load; both sources affected. Beeps and flashes for 5 seconds, both sources are turned off.
RE	Range Error.	Beeps and flashes for 5 seconds, source is turned off.
TM	Thermal Management (F2300/F2300A/F2350).	Flashes for up to 1 minute while source is off (after being on for the same time) when output $\leq$100 amperes.
WU	Warm Up (F2100/F2200 only).	Flashes after turnon until power supply stabilizes.

APPENDIX B

F2000 SERIES APPLICATION BULLETIN

SUBJECT:	DAMAGE TO ELECTRONIC RELAYS WHEN USING F2000 TIMER CONNECTED DIRECTLY TO INTERNAL CIRCUITRY		
ISSUE DATE	MARCH 1991	SERIAL NO	1991

IT IS IMPERATIVE THAT ALL F2000 USERS REVIEW THIS DOCUMENT

INTRODUCTION

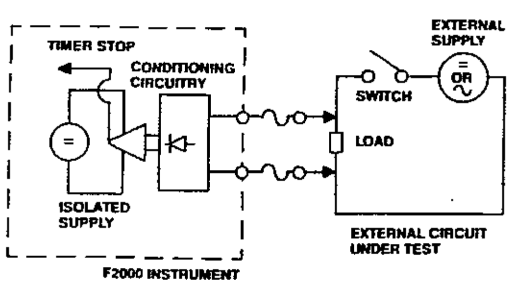
This newsletter is being issued in response to reports of damage to General Electric TYS relays. The damage occurs during inadvertent application of F2000 contact sense voltage to sensitive internal, unprotected relay logic circuitry.

REVIEW OF PROBLEM

The test procedure for the TYS relay requires that measurements be made from test points on an extender card. The unprotected test points are connected to the relay integrated circuit logic. If the F2000 Timer is connected to the test points while set to the "CONTACTS" mode the Timer internal supply voltage is applied to the relay circuitry causing damage.

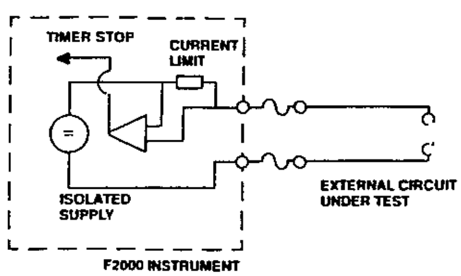
F2000 TIMER INPUT MODES

The F2000 Timer has only two terminals. The Timer input mode selector switch determines the state of these terminals.



In the "VOLTS" mode;
the terminals are passive and suitable for connection to electronic circuitry; the timer circuitry monitors the terminals for an external voltage signifying that an external source is active.

Figure 1. Block Diagram of F2000 Timer in "VOLTS" Mode



In the "CONTACTS" mode;
the terminals are active and suitable only for connection to dry unenergized contacts; an internal 30 volt current limited supply is fed to the terminals and the timer circuitry monitors the terminals for current flow signifying that an external contact is closed.

Figure 2. Block Diagram of F2000 Timer in "CONTACTS" Mode

The F2000 timer mode may be triggered into the active "CONTACTS" mode by any of the following events;

- Manual or computer selection of the "CONTACT" mode.
- Powering the instrument up or down.
- Encountering an instrument crash due to incorrect connections or software problem.

CONSEQUENCES OF INAPPROPRIATE MODE SELECTION

If the Timer input mode is changed into the "CONTACTS" mode when the F2000 Timer is connected directly to the electronic circuitry the Timer terminals will become a source of energy driving current into the relay and possibly damaging the integrated circuit components. Conversely, if the Timer inputs are connected to an external voltage supply, say the 125 volt station battery, and the mode is accidentally changed back to "CONTACTS", the external supply will feed back into the F2000 internal supply and blow the timer fuse.

Recent changes to the instrument firmware have greatly reduced the frequency and duration of Timer mode transitions into the "CONTACTS" mode during software errors and power disruptions. This has reduced the risk of damage. Even short and infrequent transient outputs from the timer circuitry can cause damage when, as in the case of the TYS relay, the Timer terminals are directly connected to the relay internal circuitry without any intervening suppression circuitry. **Always use voltage limiting protection between the F2000 timer and the relay whenever electronic circuits are directly accessed.** A suitable circuit is shown below.

RECOMMENDED PROTECTION CIRCUIT. The circuit is shown in Fig 3. Resistors isolate the two supplies; Zener diodes limit the output of the internal SENSE supply to about 4 volts at the SENSE terminals. Suitable plastic boxes, such as Pomona #2259, with Banana plugs and sockets already fitted are readily available at most electronic supply houses.

R1 = R2 = 50 kOhm 1 watt: Z1 = Z2 = 3.3 volt 1 watt zener

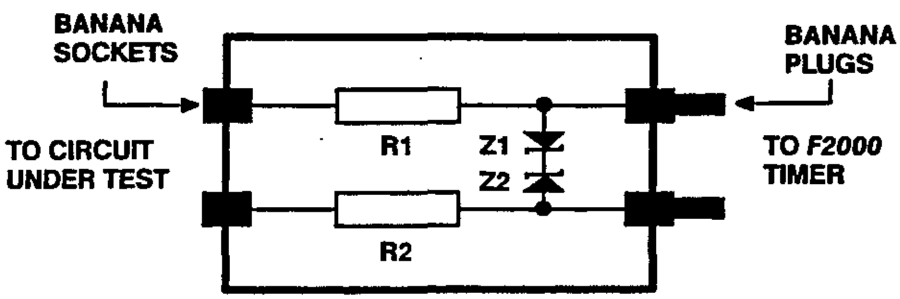


Figure 3. Protection Circuit For Use When Connecting Timer Terminals to Live or Electronic Circuitry

APPENDIX C
F2000 SERIES APPLICATION BULLETIN

SUBJECT:	INTERIM OPERATING INSTRUCTION F2350 INSTRUMENT: NEW FUNCTIONS		
ISSUE DATE	MARCH 1991	SERIAL NO	2/91/A

INTRODUCTION

Version 2.07 firmware introduces two new functions for F2350 and F2300 sources. These functions are:

1. New source assignments, "G" & "K", provide 1 milli-amp resolution on 5 and 10 Amp ranges for F2350 instruments and F2300 Slave current Sources.
2. New source assignments, "l" & "h", provide F2300 slave control in the parallel mode of the F2300 and F2350.

Modification of F2300 Slave sources is not required however the controlling F2100/F2200/F2500/F2350 instrument must have Version 2.07 or higher firmware.

SOURCE ASSIGNMENTS G & K

The new source assignments G & K provide 1 milli-amp resolution on the 5 and 10 Amp ranges of an F2350 or an F2300 slaved to an F2100/F2200/F2500. On ranges above 10 Amps the sources have resolution of 0.01 Amps. The highest range for G & K sources is 65 Amps.

The new source assignments G & K will be recognized by Protest version 3.67. This will allow simultaneous action under Protest for G or K, and I sources. This will enhance the application of F2350 instruments in conjunction with F2100/ F2200/ F2500 current sources.

Note that the F2350 or F2300 High Power Sources are capable of damaging normal F2000 sources if they are connected in parallel and used to drive loads requiring higher compliance voltages than the normal F2000 sources can sustain. When a high power source is connected in parallel with a normal F2000 source, and the combination is used to drive a burden to the point where the compliance voltage of the normal F2000 source is exceeded, the high power source will push current into the normal source. Under such conditions the thermal dissipation of the output stages of the normal source may exceed allowable limits. Users should ensure that burdens exceeding normal F2000 source capability are avoided when normal F2000 sources are used in conjunction with F2350 or F2300 sources.

SOURCE ASSIGNMENTS "l" & "h"

New source assignments "l" & "h" provide control in parallel mode for F2300 Slave Current Sources from F2350 Instruments. Protest support of "l" & "h" source assignments is not provided at this time.

The F2300 Slave must be connected to the F2350 via the A.C. Slave interface on the right hand side of the respective sources. The new assignments are only attainable with this connection completed. The connection should be made before switching either source on. Paralleling the outputs of an F2350 and an F2300 in this mode provides control of up to 320 Amps at up to 1000 Watts average or 4.2 kW peak from the front panel of the F2350. Since for a parallel range of, say, 80 amps, each source is actually on the 40 Amp range, the compliance voltage of the parallel combination is effectively twice that of one source alone. The lowest range for this combination is 10 Amps. On this range, and up to the 160 Amp range, the combination can drive higher impedance burdens than one source alone. A new 320 Amp range is available in either the "l" or "h" mode.

The Heavy Current connectors should be used whenever the combined current exceeds 50 Amps. The "GF" ground fault protection will operate if, due to unbalanced connection resistance or stray inductance, a current exceeding 8 Amps flows in the ground circuit of either of the sources. For best results, always run test leads from the red and black terminals of each source and parallel them at the load. Keeping the leads for each source close together and apart from the leads from the other source will tend to minimize current spill between the source grounds.

The current/time rating for the combination is the same as that of the individual sources next range down. However, Thermal Management is enforced when the combined current exceeds 100 Amps limiting the maximum cycle time to one minute on, one minute off.

In "l" or "h" mode the Master instrument controls the phase and amplitude of it's own source and that of the Slave to achieve the total current as set on the Master instrument front panel. Each source relies on it's own error detection circuitry to detect an out of tolerance condition. This means that the sources can in fact be used to drive separate loads. However it must be borne in mind that, while the currents are in phase, the output of each source is only one half of the displayed value.

Note: Do not connect the output of the F2350 and F2300 in parallel or interconnect them via a load when using any other source assignment than "l" or "h" unless the slave is under the control of another F2000 instrument. The Slave source output is clamped when not under the control of a Master and it will act as an uncalibrated current drain.

RANGES AND RESOLUTION

SOURCE ASSIGNMENT AND POWER MODE

L1 LOW	H1 HIGH	K1 LOW	G1 HIGH	l1 LOW	h1 HIGH
RANGE/RESOLUTION (AMPS)					
5/0.01	5/0.01	5/0.001	5/0.001	10/0.01	10/0.01
10/0.01	10/0.01	10/0.001	10/0.001	20/0.01	20/0.01
15/0.01	15/0.01	15/0.01	15/0.01	30/0.01	30/0.01
20/0.01	20/0.01	20/0.01	20/0.01	40/0.01	40/0.01
25/0.01	25/0.01	25/0.01	25/0.01	50/0.01	50/0.01
30/0.01	30/0.01	30/0.01	30/0.01	60/0.01	60/0.01
40/0.01	40/0.01	40/0.01	40/0.01	80/0.01	80/0.01
50/0.01	50/0.01	50/0.01	50/0.01	100/0.01	100/0.01
80/0.1	80/0.1	65/0.01	65/0.01	160/0.1	160/0.1
160/0.1	160/0.1			320/0.1	320/0.1

APPENDIX D
F2000 SERIES APPLICATION BULLETIN

SUBJECT:	**USE OF F2825 MULTIPLE SOURCES OPTION WITHOUT F2010 MINICONTROLLER**		
ISSUE DATE	**MARCH 1991**	**SERIAL NO**	**3/91**

INTRODUCTION

Firmware Revision 2.07.

F2000 Firmware revision 2.07 includes the selection and operation of F2825 multiple sources option from the front panel of any F2825 equipped F2000 instrument with or without an F2010 mincontroller.

Instrument firmware revisions up to Version 2.06 allowed control of F2825 functions only from the F2010 Minicontroller. The multiple source assignment could only be made with the F2010 connected.

Definitions

The F2825 Multiple Sources option allows simultaneous control of either amplitude or phase for multiple F2000 sources from one control point. Multiple sources assignment can only be made on instruments fitted with the F2825 option.

Multiple Source assignments are as follows:

VM – Voltage Multiple source IM – current (I) Multiple source	For F2100/F2200 or F2500
LM – Low power mode Multiple source HM – High power mode Multiple source	For F2350 or F2300

The F2010 Minicontroller is a hand held control unit providing enhanced, centralized control of amplitude, phase and frequency on one or more sources in an F2000 system.

RANGE MANIPULATION

Multiple source assignment can only be made to sources on the same range.

All similar (V, I, L or M) multiple sources must be disabled to allow a change of range. Changes made on any source will be reflected on all other similarly assigned sources.

HARMONIC MANIPULATION

The harmonic setting of individual sources within a Multiple Source can be changed, if the individual source is disabled, by manipulation of the individual source "HERTZ" control. The harmonic of other sources within the Multiple Source is not affected. Thus it is possible to have control over amplitude, phase and frequency of a Multiple Source containing sources set at different harmonics.

AMPLITUDE MANIPULATION

All similar multiple sources will have the same amplitude. The amplitude of the multiple sources becomes that of the last source assigned multiple source status.

Amplitude changes may be made from the front panel of any source and will be reflected on all other similarly assigned sources.

Amplitude control operation is independent of whether the instruments are in SET or RAMP mode. SET and RAMP mode cause amplitude changes on all similarly assigned sources in the normal manner of SET or RAMP operation.

PHASE MANIPULATION

Similarly assigned multiple sources may have the same or different phase angle settings. Phase angle setting is not modified when multiple source assignment is made.

Phase angle changes made on any instrument which is in the SET mode will affect that source only. In other words, similarly assigned multiple sources, regardless of whether they are in the SET or RAMP modes, will not react to phase angle changes made on an instrument which is in the SET mode. Thus, changes to the phase angle setting of a source, whose instrument is in the SET mode, will affect the phase relationship between this source and other similarly assigned sources.

Phase angle changes made on any instrument which is in the RAMP mode will be reflected as offsets to the phase angle of all similarly assigned multiple sources. In other words, if the phase angle of a multiple source, whose instrument is in the RAMP mode, is advanced, say, ten degrees, all similarly assigned sources will advance by ten degrees, regardless of whether their instruments are in the SET or RAMP mode. Thus, changes made to the phase angle setting of a source, whose instrument is in the RAMP mode, will not affect the phase relationship between this source and other similarly assigned sources.

FREQUENCY MANIPULATION

Control of frequency (other than the selection of harmonics) is independent of F2825 option function. The operating instructions for frequency control are not affected by the new multiple source functionality.

APPENDIX E
F2000 SERIES APPLICATION BULLETIN

SUBJECT:	USE OF F2920 FIRMWARE PHASE INTERFACE OPTION WITH F2010 MINICONTROLLER		
ISSUE DATE	FEBRUARY 1991	SERIAL NO	4/92/A

INTRODUCTION

This application bulletin serves as interim operating instructions for the F2920 firmware phase interface option available with ROM version 2.09 & higher. The new option may be used instead of the F2845 dual phase interface board option, which occupied one slot of the F2200/F2500 motherboard. The new firmware option does not require a slot on the motherboard.

Application of the F2920 Option

The F2920 phase interface option is used to test circuit breaker advance time on auto-synchronizer relays. The option provides quick, simple, repeatable and accurate tests on this important relay function. Traditional test methods using chart recorders or oscilloscopes require user subjective interpretation of waveform displays leading to loss of repeatability and accuracy.

Autosynchronizers are used to control the closing of circuit breakers connecting an incoming generator to a running system. The autosynchronizer monitors the voltage from the two sources and initiates circuit breaker closing, providing amplitude and frequency are within pre-set limits, when the two sources are synchronized. Minimum disturbance to the generator and the system occur if the breaker contacts close at exact synchronism.

Because the two sources are normally running at slightly different frequencies the sources will only be within the allowable range for a short time, The circuit breaker advance time feature of such relays is intended to initiate closing of the circuit breaker in advance of anticipated synchronization by a time equal to the closing time of the breaker. Breaker contact closure should then occur exactly at synchronism.

See F2000 manual Section 3 Page 16 to 19 for general phase interface application information.

Advantages of the F2920 Firmware Option Over F2845

- Does not require a slot on the motherboard, leaving a slot available for new advanced options such as Satellite Receiver Interface or Second Transient Slave Interface
- Is more tolerant of high slip rates
- Synchronism defined at any angle (F2845 uses nearest zero)
- Does not require prior selection of Accuracy Range(1° - 0.1°)
- Automatically sets defined phase displacement before test start to enhance test repeatability.

Firmware Support for Phase Interface Options

The new option is supported by F2000 Firmware revision 2.09 or higher. Support for the F2845 board will continue. If the option is fitted to an instrument which has the F2845 board installed the firmware will continue to use the F2845 board, once the F2845 board is removed the firmware will use of the F2920.

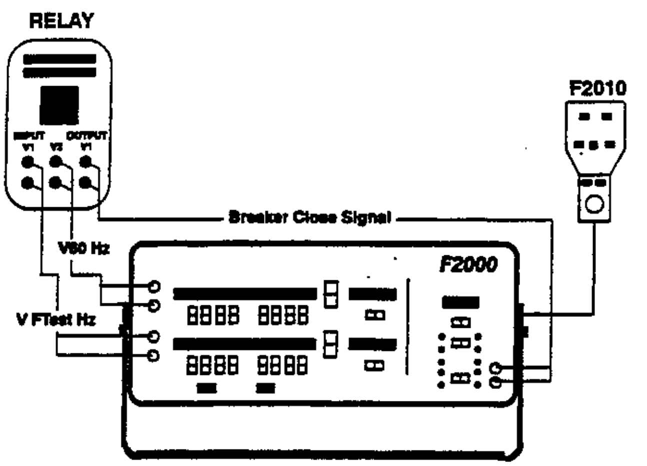
Option Installed Indication

Indication of an F2000 instrument configuration may be obtained, with the instrument powered up, sources disabled/ off, and system output off, by pressing and holding the MASTER/SLAVE switch in the SLAVE position. The indication "PH4" appears in Source 2 Amplitude display area if the option is fitted. Refer to the F2000 manual Section 2 Page 8 for information on other option and configuration indication information.

Equipment Required

To use the F2920 phase interface the following equipment is required.

1. Either an F2200 or an F2500 equipped with:
   a) Firmware revision 2.09 or higher, and,
   b) F2920 Phase Interface option.
2. An F2010 Mini Controller (ProTesT support for this option will be made available in 1993).



F2000 TEST INSTRUMENT

Figure 1. Typical Test Setup

USING THE F2920 TO TEST AUTOSYNCHRONIZER C.B. ADVANCE TIME

General

- The two voltage sources of an F2200 or F2500 instrument are used to supply the relay under test,
- The relay is configured to respond with a close signal in advance of synchronism.
- The F2000 sources are set to slip against each other to simulate running and incoming supplies,
- The SENSE input of the F2000 is used to detect relay operation and display the relay C.B. advance time.

Operating Instructions

Requirements for a F2920 valid phase interface test setup. Several conditions must be met before the F2000 will perform a phase interface test using the F2920. A list of these conditions follows.

- The phase interface option must be installed.

- The timer mode must be set to START.
- The Mini-Controller mode must be set to FREQUENCY.
- The Mini-Controller source selection must be either SRC 1 or SRC 2, it cannot be BOTH.
- The starting frequency must be equal to the base frequency, either 50 or 60 Hz.
- The test frequency may be Value A or Value B, but it must be different from the starting (base) frequency.
- The initial starting phase difference must be a multiple of 60°.
  - Source 1 phase is set to zero automatically when the test is run.
  - Phase relationship is set via Source 2. Valid source 2 phase settings are; 0, ±60°, ±120°, ±180°, ±240°, or ±300°.
  - If the user sets Source 2 to a "non-60°" phase angle the firmware will automatically advance the phase angle (and display) to the next 60° multiple the first time the test is run. For example: if the user sets Source 2 phase to -90° the firmware will change the phase to -60°.

Setting Up for an Autosynchronizer Test

- Consult the autosynchronizer relay instructions to determine relay connections and operating requirements. Set the relay up for test.
- Connect the F2000 Instrument source outputs to the relay inputs.
- Power up F2000.
- Select the SENSE input mode to suit the output of the relay (contacts/volts etc.). Connect the F2000 Instrument SENSE input to the relay "CLOSE" output.
- Plug the F2010 Minicontroller in to the D232 socket on left side of F2000.
- Select F2000 sources as voltages, set amplitudes as required by relay.
- Power up relay and make any adjustments required for test.
- Turn F2010 Minicontroller ON.

Running the Test

- Set Source 1 phase to Zero
- Set Source 2 phase to the desired initial phase, for example 180°.
- Set Source 2, Frequency, Value A, the starting frequency, to be the same as the base frequency, i.e. 60 Hz (or 50 Hz).
- Select Source 2, Frequency, Value B. Set Value B to the test frequency, for example. 59.96 Hz.
- Select Source 2, Frequency, Value A.
- Ensure that relay is ready for test.
- Initiate test by pressing Delta Value.
- Observe Timer starts downcounting from a time equal to a fraction of the slip period. For the phase and frequency given above this value is 12.5 seconds.
- Observe that if relay does not operate on first synchronization the Timer resets to full slip period time and resumes downcounting towards next synchronism.

- Observe Timer stops when relay operates displaying the time remaining before synchronism — the circuit breaker advance time.
- Record the advance time and calculate the close angle error as described below.

Calculating the Accuracy of the Relay Under Test

The setting of the relay circuit breaker advance function is time and the measured response is also a time. However the important factor in synchronizing a generator to a system is the *Close Angle Error* (CAE), that is the phase difference between the sources when the circuit breaker contacts close. Assume that the circuit breaker advance time exactly matches the circuit breaker time, and this can only be verified by timing the circuit breaker. The relationship between the error in circuit breaker advance time and close angle error depends on the slip frequency. At low slip rates a large time error will result in only a small close angle error, but at high slip rates even small time errors cause large close angle errors.

$$CAE = (\text{Set Time} - \text{Measured Time}) * \text{Slip Frequency} * 360$$

Where;

Set Time = Relay advance time setting in Seconds
Measured time = Timer display at the end of the test in Seconds
Slip frequency = Frequency difference between the sources in Hz.

INSTRUMENT ACTION DURING A PHASE INTERFACE TEST

The following is a step by step description of the F2000 actions after the user initiates a test using the phase interface.

1. The F2000 checks for a valid test setup, if the test setup is not valid, then the mini-controller bleeps.

2. The F2000 sets the phase relationship which is defined by the source 2 phase display. The phase of Source 1 is set to zero. The Phase of Source 2 is advanced to the nearest 60 degree multiple that is greater than, or equal to, the set phase.

   For example, if the user sets a Source 2 phase of 45 degrees, then the F2000 would change it to 60 degrees. If the user sets a phase of −150 degrees, then the F2000 would change it to −120 degrees. The phase of source 1 is simultaneously set to zero.

3. The F2000 sets both sources to the same clock for several cycles to ensure phase update and ensure a known phase relationship.

4. The Source selected on the F2010 as that which is to change frequency is set to the variable frequency clock. Note however that the variable frequency clock is set to the base frequency so phase relationship is maintained.

5. The F2000 calculates the time required for the sources to slip from the initial conditions to synchronism once the test source is moved to the test frequency and preloads this time into the instrument timer. The initial phase relationship between the sources defines the angular distance to synchronism and the difference between base frequency and test frequency is the angular velocity.

6. The F2000 waits for one second to allow the relay to absorb the phase change.

7. The frequency of the test source is changed from the base frequency to the test frequency at a zero crossing. The timer is started, in the downcount mode, at the same zero crossing.

8. The timer uses the predicted time as the starting point, and counts down to synchronism, with zero equaling synchronism. The relay output stops the timer, which then displays the remaining time to synchronism – the relay circuit breaker advance time.

9. If the relay does not operate on the first pass through synchronism, i.e. when the timer counts down to zero, the timer is pre–loaded with the full slip period and immediately starts counting down again.

10. If the relay actually stops the timer after coincidence, the timer displays the full slip cycles time, minus the relay retard time.

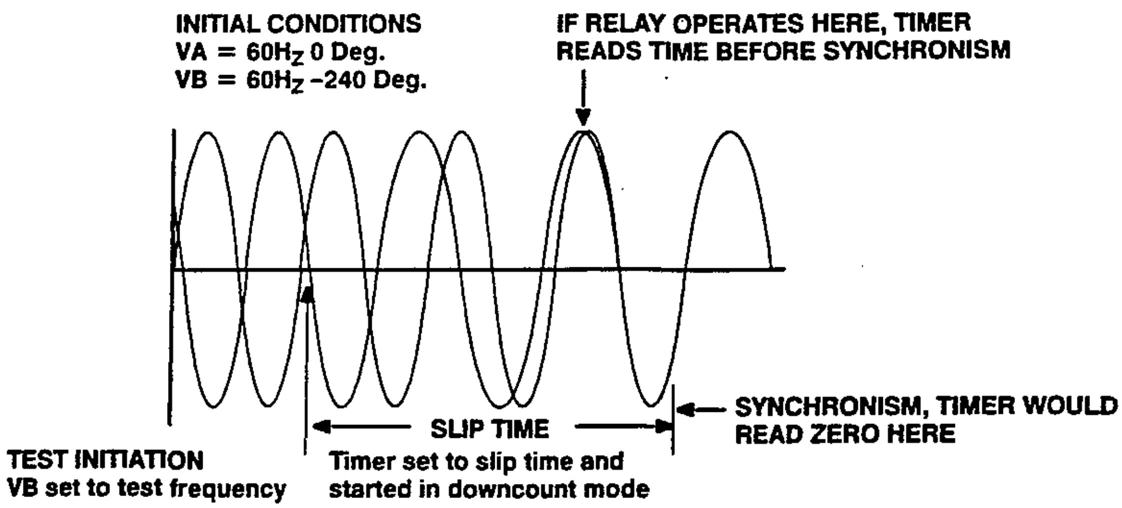


Figure 2. Circuit Breaker Advance Time Test Conditions.