EFT/B-100™

OPERATORS MANUAL

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INTRODUCTION

The Compliance Design EFT/B-100 is a rugged, flexible, and easy-to-operate system for testing immunity to electrical fast transients. The EFT/B-100 utilizes all solid-state circuitry to generate the surges necessary for assessing compliance to EFT immunity standards, including IEC 801-4 and IEC 1000-4-4.

Bursts of electrical fast transients are generated by the switching of inductive loads. Equipment is exposed to them via direct conduction to power leads, and by capacitive coupling to signal and control leads. An adequate level of immunity to these signals is necessary for reliable product operation, and is rapidly becoming a mandatory regulatory requirement in many countries.

This manual describes how the EFT/B-100 works and how to use it to test equipment for immunity to electrical fast transients.

SAFETY FIRST

In order to help ensure the safety of personnel, monitoring equipment, and the equipment under test, several safety considerations should be kept in mind. By its very nature, this product produces hazardous voltage and currents. The EFT/B-100 generates peak pulse voltages of 4000 volts. In addition, some tests may involve attaching the generator output externally to the power leads of equipment under test. The AC power supply voltages of 120 and 240 VAC are hazardous. To minimize the risk of shock and/or collateral equipment damage, several factors should be kept in mind.

NO USER SERVICEABLE PARTS:

There are no user serviceable parts in the EFT/B-100. Users are urged to contact the manufacturer if there is a question over functionality or calibration. Inside the EFT/B-100, there are several sources of electrical hazard. The first danger is the AC line voltage. There are two AC connections--the power supply for the instrument, and the backfiltered power for the equipment under test. The second source of danger is the internal high voltage supply, which generates up to 4500 volts. Although this supply is current limited at 7 milliamperes, it is still quite dangerous. There is also a bulk energy storage capacitor of 2 uF, which is charged to the level of the high voltage supply. The energy stored in this capacitor may reach 10 joules, which can be dangerous.

INSULATE AND SECURE EXTERNAL CONNECTIONS:

As described later in this manual, the generator output is generally used in four ways:

1. Injection of transients via the **EUT POWER OUT** port

2. Calibration

3. Injection of transients via an external backfilter

4. Capacitive coupling of transients

For the first application, coupling occurs to the equipment power line internal to the EFT/B-100, so the user is insulated from hazardous voltages. In the other applications, power is drawn from the **COAX OUTPUT** connector. Here, the user is responsible for insulating and securing the connections.

When checking calibration, precautions must be taken to see that the waveform monitoring equipment can withstand the available peak voltages. The user safety problem is especially acute in the last two applications.

When injecting transients via an external backfilter, the user must connect from the COAX OUTPUT to the power line or lines that are to be tested through "Y" rated 33 nF capacitor(s). This procedure is employed when the equipment being tested requires higher power than the internal backfilter can handle (max 15 A at 120/240 VAC) or multiphase connection. The power connections in such a situation are hazardous and must be made in an electrically safe manner. In addition, in this application, the transient voltages are brought outside the instrument are hazardous as well.

When the capacitive clamp is used, the center conductor of the coaxial output is connected to the 1 meter long triangular metal clamp section. Thus the entire 1 meter clamp is "live" with the transient voltage when the generator is running. Care must be taken to avoid contacting this clamp during surge testing.

USER CONTROLS

FRONT PANEL:

Figure 1 shows the front panel of the EFT/B-100. The description below is keyed to the numbers on the figure, and describes manual operation using the front panel controls. If you have purchased the remote programming option, be sure that the **CONTROL OPTION** switch is set to MANUAL for operation from the front panel. Also, see the manual supplied with the remote option.

MAIN CONTROLS

Controls **1** through **5** control the initiation, duration, and polarity of the transient waveform. Controls **1** through **4** contain indicator LEDs which indicate the operating state of the unit.

1. The **RUN** control starts a transient pulse train. The duration of the pulse train is controlled by the **STOP** and **TIMER OVERRIDE** switches. Once the **RUN** switch has been depressed, the unit will run until it is stopped manually by the **STOP** switch, or automatically by the internal timer. When the unit is running and generating transients, the **RUN** LED indicator will be lit.

2. The **STOP** switch stops the generation of transients. The operation of the **STOP** switch is simple and unconditional. If the unit is running, depressing the **STOP** swtich will stop transient generation. The **RUN** LED will turn off, and the **STOP** LED will light. Depressing the **STOP** switch when the unit is already stopped has no further effect.

3. The **POLARITY** control determines whether positive or negative polarity transients will be generated. Polarity is referenced to the power ground of the EFT/B-100 and the equipment under test. The switch is a push-button which toggles polarity each time it is depressed. Dual LEDs indicate which polarity has been chosen. When the unit is initialized at power-up or by use of the **RESET** switch, positive polarity is selected as the default.

4. The **TIMER OVERRIDE** control toggles an internal timer. When **TIMER OVERRIDE** is off, the internal timer automatically stops the generator after 15 minutes have elapsed. The purpose of the internal timer is to prevent the accidental overstressing of equipment attached to the generator if the unit is set to **RUN** and the operator neglects to manually stop the test sequence. If the **TIMER OVERRIDE** is on, as indicated by the LED, the internal timer is inoperative, and the transient sequence will continue until stopped by use of the **STOP** or **RESET** buttons.

5. The **RESET** control resets the unit to its power up defaults. These are:

    Unit is stopped

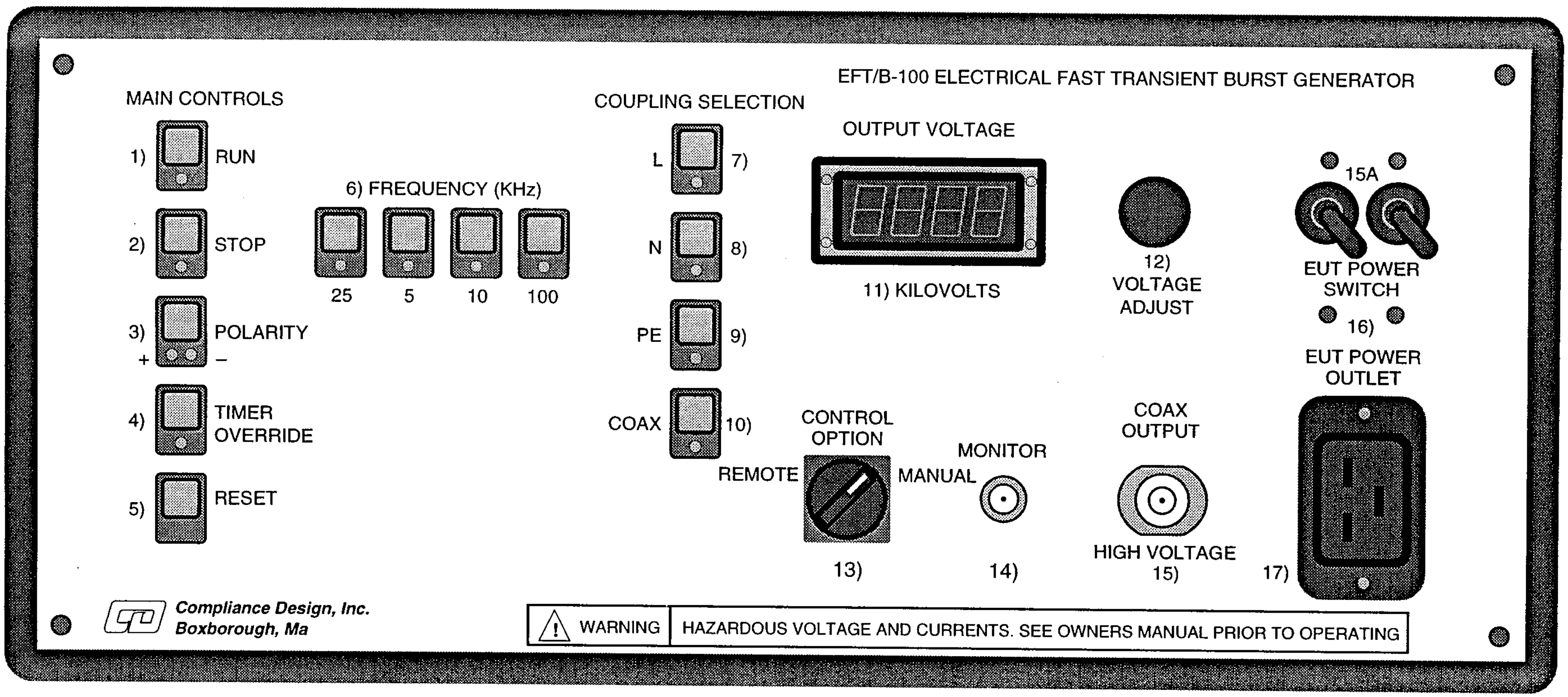

EFT/B-100 ELECTRICAL FAST TRANSIENT BURST GENERATOR
MAIN CONTROLS
1) RUN
2) STOP
3) POLARITY
+ –
4) TIMER OVERRIDE
5) RESET
6) FREQUENCY (KHz)
25
5
10
100
COUPLING SELECTION
L 7)
N 8)
PE 9)
COAX 10)
OUTPUT VOLTAGE
11) KILOVOLTS
12) VOLTAGE ADJUST
15A
EUT POWER SWITCH
16)
EUT POWER OUTLET
17)
CONTROL OPTION
REMOTE
MANUAL
13)
MONITOR
14)
COAX OUTPUT
HIGH VOLTAGE
15)
Compliance Design, Inc.
Boxborough, Ma
WARNING
HAZARDOUS VOLTAGE AND CURRENTS. SEE OWNERS MANUAL PRIOR TO OPERATING

Figure 1

Positive polarity selected
Timer Override is disabled, i. e., the internal run/stop timer is operative
Pulse repetition rate is set to 2.5 kHz, with a 15 ms burst duration
All coupling relays are disconnected

FREQUENCY

6. The four controls in this group, highlighted on Figure 1 as number **6** , select the output frequency and duty cycle of the transient burst. Depressing a control in this group selects one of 2.5, 5, 10, or 100 kHz as the pulse repetition rate within a pulse burst. LED indicators indicate the selected frequency. The burst width is 15 ms at frequencies of 2.5 and 5 kHz. At 10 and 100 kHz, the burst width is set to 1 ms. In all cases, the burst repeat period is 300 ms. These parameters are automatically adjusted as frequency is changed to match the requirements of IEC 801-4 and IEC 1000-4-4.

COUPLING SELECTION

The coupling selection controls select which leads the transients are applied to. Three of the controls, marked **L, N, and PE,** connect to the power line through the internal backfilter. The backfilter is a single phase filter with a maximum current capability of 15 Amperes, and may be operated at line voltages of 120/240 VAC. If the equipment that you are testing requires more than 15 Amperes of supply current, or utilizes three phase power, you must use an external backfilter. The fourth control, **COAX**, connects the output of the generator to the coaxial port on the front panel. It is used for connecting the generator to external loads, such as a multiphase backfilter or a 50 ohm termination for waveform verification (see the section on calibration).

7. The **L** pushbutton toggles connection of the generator to the "line," "hot," or black lead of the **EUT POWER OUTLET.**

8. The **N** pushbutton toggles connection of the generator to the "neutral," or white lead of the **EUT POWER OUTLET**.

CAUTION: In the United States, when 240 volt power is used, both the black and white leads will be carrying 120 VAC with respect to the earth lead. This is because the black and white leads are out of phase, yielding a line-to-line voltage of 240 VAC with ground "in the middle."

9. The **PE** pushbutton toggles connection of the generator to the protective earth, or green lead of the **EUT POWER OUTLET**.

The three line connection controls may be selected in any combination. That is, any individual line, or any combination of lines, may be attached to the generator. Note that the line connection controls and the **COAX** control are mutually exclusive. Selecting any line control will clear the **COAX** output. Similarly, selecting the **COAX** output will turn off all line connections.

10. The **COAX** pushbutton toggles connection of the generator to the coaxial connector on the front panel. The output impedance is 50 ohms. The **COAX OUTPUT** is primarily used for:

- Connecting to the IEC standard capacitive clamp for coupling fast transients to signal and control leads
- Connecting to an external backfilter for the testing of equipment not supported by the internal backfilter. This is only necessary for single-phase equipment drawing more than 15 Amperes and for units requiring three phase power.
- Connecting to an external 50 ohm or 1000 ohm load for checking the calibration of the transient waveform. **CAUTION**: To prevent injury or damage to associated equipment, use components capable of withstanding the 4000 volt peak surge capability.

PULSE VOLTAGE LEVEL

11. The **OUTPUT VOLTAGE** meter shows the peak open circuit amplitude of the output transients. It is calibrated in kilovolts.

12. The **VOLTAGE ADJUST** control sets the output amplitude.

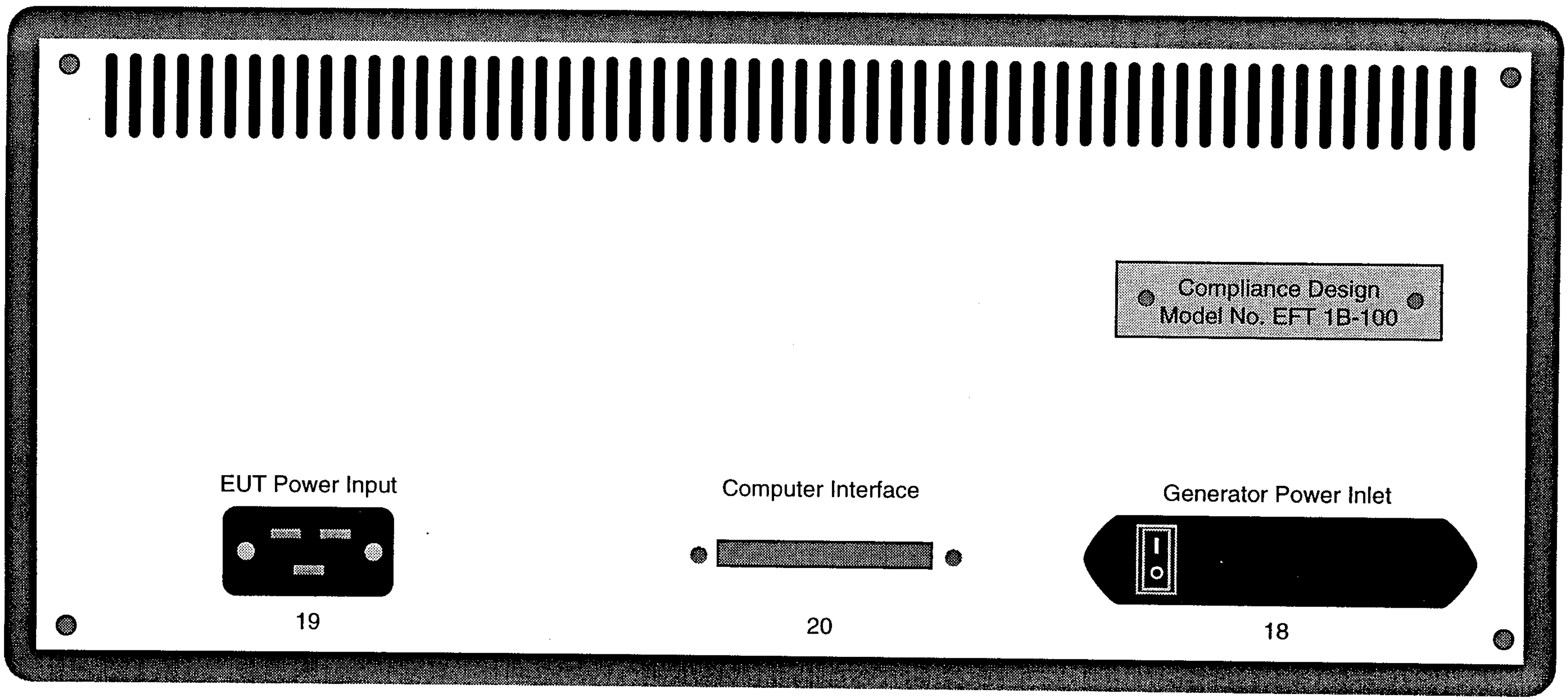
MANUAL/REMOTE CONTROL

13. If you have purchased the remote programming option, the **CONTROL OPTION** switch selects between front panel operation (**MANUAL** position) and operation under remote computer control (**REMOTE** position). If the remote programming option is not installed, the unit operates in manual mode regardless of the control setting. For information on remote control of the EFT/B-100, see the remote programming manual.

SIGNAL OUTPUT AND MONITORING

14. The **MONITOR OUTPUT** provides a pulse derived from the generator's high voltage output. When terminated in its source impedance of 50 ohms, the monitor output is attenuated 100:1 relative to the generator output, so the peak voltage available voltage is 40 volts. If the output is connected to a high impedance, the peak available voltage will not exceed 80 volts. This output is primarily used to monitor operation. Calibration verification of the waveform must be done using the **COAX OUTPUT** and a high voltage 50 ohm termination.

15. The output of the generator is available at the **COAX OUTPUT** connector. The output has a dynamic impedance of 50 ohms. This output is used for checking calibration of the generator, and connecting it to external loads, such as the IEC capacitive coupling clamp or a high powered backfilter. The connector shield is returned to chassis ground. **CAUTION**: High voltage is present on the center conductor when the generator is operating.



Compliance Design
Model No. EFT 1B-100
EUT Power Input
19
Computer Interface
20
Generator Power Inlet
18

Figure 2

EUT/BACKFILTER

16. The **EUT POWER SWITCH** is a 15 Ampere circuit breaker inserted in series with the **EUT POWER OUTLET**. Turning the breaker on connects power to the outlet.

17. The **EUT POWER OUTLET** serves two functions. It provides backfiltered 120/240 VAC power to the equipment under test (EUT), and provides a connection for coupling the generated electrical fast transients onto selected leads of the power cable. The **EUT POWER OUTLET** can supply up to 15 Amperes, controlled by the **EUT POWER SWITCH** and circuit breaker. The voltage level at the power outlet is determined by the voltage supply connected to the **EUT POWER IN** connector on the back panel.

REAR PANEL:

Figure 2 shows a view of the rear panel connectors.

18. The EFT/B-100 receives power via the **AC POWER** connector. This connector is an input module which also contains the power switch, the voltage selector, and the input fuse. When the unit is turned on, it enters a power up state identical to that produced by the **RESET** control.

When you receive your EFT/B-100, this module will be preset at the factory for the voltage you specified in your order (120 or 240 VAC). The voltage is selected by removing the voltage selection assembly, rotating it, and reinserting it so the value of the desired operating voltage is highlighted on the module. You should be careful, of course, to always operate the instrument at the voltage it is set for.

Use a 1 ampere fast-blow 3AG type fuse for 120 volt operation and a 0.5 ampere fuse for 240 volt operation.

19. Power for the equipment under test is connected to the rear panel **EUT POWER IN** connector. The power for the EUT (equipment under test) is independent of the power used to operate the instrument. This allows the testing of 120 and 240 VAC powered equipment regardless of the voltage used to run the generator. **CAUTION:** Be careful to connect the this power cord to the correct voltage for the equipment you are testing!

20. The 37-pin "D" style **REMOTE** connectors are for connection to the interface cards in a PC computer. These connectors are present only if you have ordered the remote programming option.

THEORY OF OPERATION

The construction of the EFT/B-100 is summarized in the block diagram of Figure 3. The unit is comprised of these functional blocks;

- high voltage transient generator
- relay matrix for polarity and output selection
- backfilter
- timing and control logic

The high voltage transient generator is conceptually an electronically switched RC circuit. The high voltage supply, which can generate voltages from 0 - 4500 volts, continually charges the bulk energy storage capacitor to the desired operating voltage. The bulk energy storage capacitor is used to provide a "flywheel" effect. Because the output waveform consists of low duty cycle bursts of high amplitude transients, the ratio of peak to average power is very large. Energy is drawn from this capacitor to charge the transient energy storage capacitor. When a trigger pulse is received by the FET switch, the transient energy storage capacitor discharges through a passive pulse shaping network to generate a 5/50 (risetime/pulsewidth) ns pulse. The passive componets located between the FET switch and the relay matrix shape the pulse to deliver the desired dynamic impedance of 50 ohms and the necessary pulse width.

The electronic switch uses power MOSFETS in order to meet the requirements of the new IEC 1000-4-4. It is possible to generate transients of the appropriate rise time and pulsewidth using gas discharge devices such as thyratrons and krytrons. While these have their advantages--combining fast rise time with an extremely low resistance when triggered--they suffer from a fundamental limitation. All gas discharge devices rely on the ionization of a gas. Once a discharge occurs, a certain "dark period" is necessary for them to regain their full insulating voltage. They cannot be retriggered until this rest period is completed. Thus, while some gas-discharge base devices have been built for simulating the 5 kHz pulses required by IEC 801-4, none are capable of operating at the 100 kHz repetition rates required by IEC 1000-4-4. Power MOSFETS, on the other hand, are semiconductor devices which can switch and recover in sub-microsecond times. The requirement for high speed operation is more than regulatory: the higher operating rates are necessary to yield a realistic simulation of the actual transients experienced in the field.

The relay matrix serves two functions: polarity reversal and output coupling selection. Since the generator utilizes a floating design, the polarity relays establish polarity by selecting which output lead to ground and route the remaining lead to the output coupling relays. Output coupling is made by selecting the appropriate SPST relays. The output is either directed to the **COAX OUTPUT** connector or to selected leads at the **EUT POWER OUTLET.** These outputs are exclusive--the coaxial output cannot be activated at the same time that any of the EUT power leads are coupled. Selecting the COAX OUTPUT automatically clears (opens) any EUT power relays, and vice-versa.

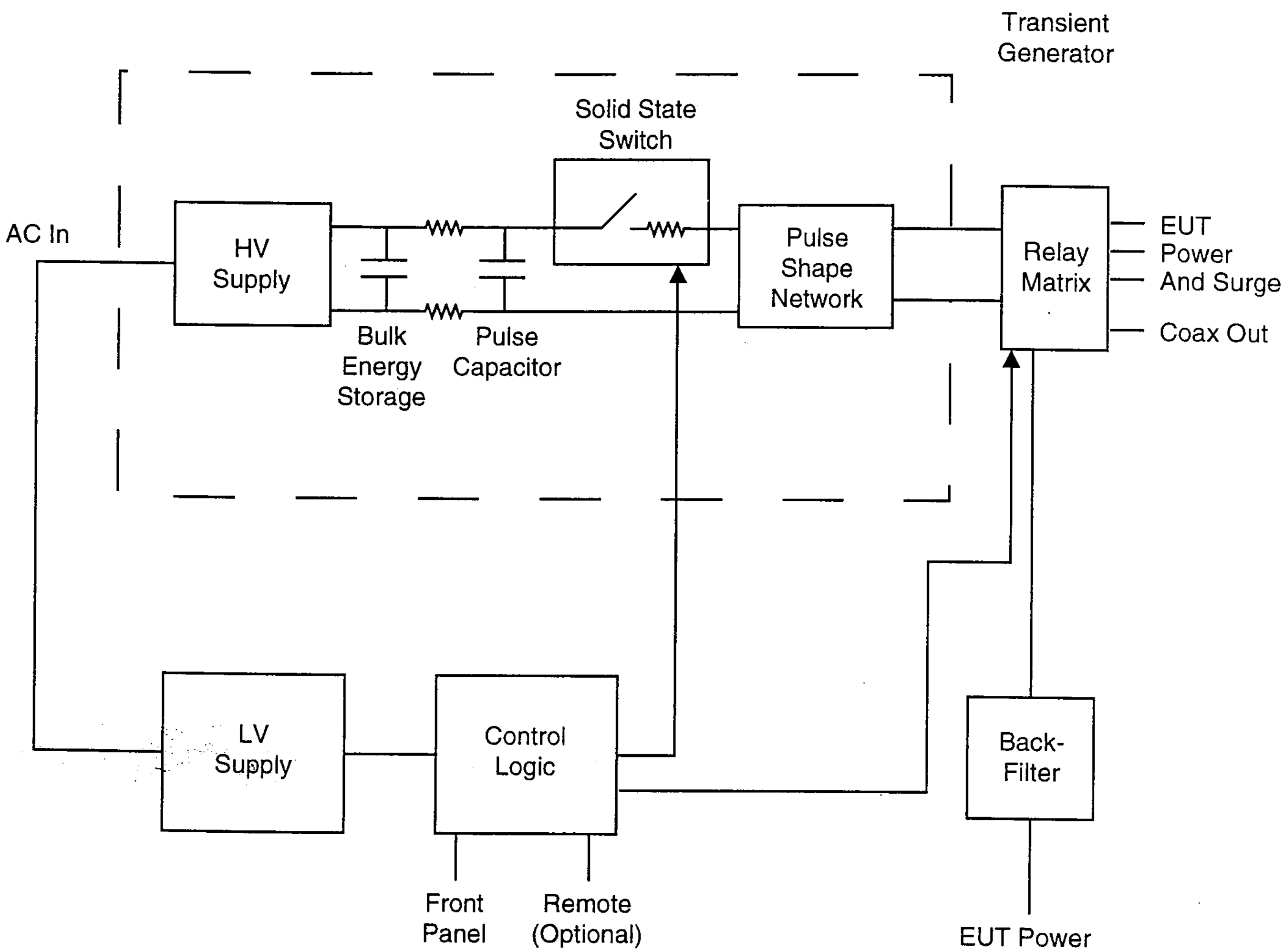

Transient
Generator
Solid State
Switch
AC In
HV
Supply
Pulse
Shape
Network
Relay
Matrix
EUT
Power
And Surge
Coax Out
Bulk
Energy
Storage
Pulse
Capacitor
LV
Supply
Control
Logic
Back-
Filter
Front
Panel
Remote
(Optional)
EUT Power

Figure 3

The IEC standards require that electric fast transients be injected directly on the AC power of the equipment under test through .033 uF capacitors, and that the transients be isolated from the AC line. The required coupling capacitors are built into the backfilter. The backfilter readily passes 50/60 Hz AC power to the equipment uner test, but inductively decouples the supply side of the line from the transients. This disconnects the power supply--and any parallel connected equipment--from the high frequency energy contained in the fast transients. Thus, all of the energy of the fast transients is directed to the equipment under test through the **EUT POWER OUTLET**.

The timing and control logic is the interface between the front panel (or the remote control, if installed), the high voltage transient generator, and the relay matrix. It monitors switch inputs, controls the status indicators, controls the timing and generation of trigger pulses, and operates the relay matrix.

CALIBRATING THE EFT/B-100

Your EFT/B-100 is factory calibrated, and has no user adjustments. User calibration consists of verification that the following conditions are met:

1. transient waveform meets IEC requirements

2. pulse repetition rate and burst width meet specificied tolerances

3. coupling relays are functional

4. EUT AC power is available at the front panel.

We will examine each of these in turn.

VERIFYING THE TRANSIENT WAVEFORM

The transient waveform must meet these requirements:

- The rise time must be 5 ns, +/- 30%
- The pulse width, measured at half height, must be 50 ns +/- 30%
- The closed circuit (50 ohm load) and the open circuit (1K or greater load) output voltages must be within 20% of the designated levels.

Because the open circuit voltage can reach 4 kV, and because of the fast rise times involved, accurate measurement of the waveform can be difficult. The combination of high frequency and high voltage places unusual demands on the measuring instrumentation. A high bandwidth oscilloscope must be employed, and its input must be adequately protected. To produce a measurement error of under 5% from a 5 ns risetime pulse, the entire system must have a bandwidth in excess of 210 MHz; for 1% accuracy, system bandwidth must exceed 490 MHz (source IEC 1000-4-4). Not all probes exhibit the same behavior under large signal conditions as under small signals, and few attenuators have the high voltage capability necessary to withstand the maximum surge voltage without arcing. There are many considerations involved in selecting and verifying the performance of the required measuring instruments. We have found that the following equipment yields accurate results:

Oscilloscope: Tektronix TDS-520 (500 MHz digital oscilliscope)

50 Ohm Load/40 dB attenuator: Weinschel Model No. 5741

High Impedance Probe: Phillips PM9100/001 probe, 100X, 4kV peak rating. Note that when used in conjunction with a 1000 ohm load, it may be necessary to tap the load at 50% because the maximum surge voltage approaches the probe rating. Any ringing will exceed the probe's rating, causing an internal arc.

Good high frequency measurement technique must be employed. Waveform verification measurements are taken at the **COAX OUTPUT**. Short, 50 ohm coaxial cables should be used when a 50 ohm load is employed. When the 1000 ohm load is attached, it should be brought out through a short (6 inches or less) cable to minimize distortion due to mismatch reflection. Measurements should be taken in both polarities, and the operation of the **COAX** relay switch should be verified.

Verification is performed by selecting a test voltage, running the unit, and examining the resulting transient waveform. In addition to checking rise time, the operator should check the waveform for droop over the duration of the 1 and 15 ms pulse bursts.

CHECKING REPETITION RATE, BURST WIDTH, AND DUTY CYCLE:

Using the setup above, check the interpulse spacing, the burst width, and the burst repetition period. It should be noted that the equipment used to measure these parameters is less critical than that used for waveform verification. Since the shape of the pulse is not at issue, these parameters can be checked at the monitor port with a 100 MHz oscilloscope.

VERIFYING RELAY MATRIX OPERATION:

The relay matrix controls the polarity of the output waveform, and directs the transients to the **COAX OUTPUT** and the various leads of the **EUT POWER OUT** connector. The operation of the polarity relays and the **COAX OUTPUT** relay should be checked while verifying the transient waveform (see above). To check the operation of the **L, N,** and **PE** relays:

1. Disconnect the EUT AC POWER IN cord from the rear panel.

2. Prepare a short power cord with insulation removed from the three leads.

3. Attach a fast, high voltage probe to each lead in turn and verify that transients appear when the corresponding relay is activated.

Note that the waveforms checked this way will exhibit some distortion relative to those at the 50 ohm **COAX OUTPUT**. This is normal, and unavoidable because of the stray parasitic impedances introduced by the power wiring.

CHECKING THE EUT POWER OUTLET:

The only equipment needed to check the EUT power outlet is a voltmeter rated for 250 VAC and an ohmmeter. The checks performed are for connectivity:

1. With the unit off and disconnected from all power, check that the earth connector on the **EUT POWER OUTLET** is returned to the chassis using an ohmmeter.

2. Connect AC power to the **EUT POWER IN** connector on the back panel. Either 120 or 240 VAC may be used. **WARNING:** *Check that you are using the* ***EUT POWER IN*** *connection, not the instrument power (labeled* ***AC POWER****). The instrument power lead is not necessary for this check. More importantly, it is essential that the instrument power match the setting on the AC input module to avoid internal damage. Since EUT power is simply passed through the internal backfilter to the front panel, the voltage used is at the choice of the user.*

3. Connect a voltmeter to the **EUT POWER OUT** socket. Verify that the applied voltage is present when the **EUT POWER SWITCH** circuit breaker is closed, and that the measured voltage drops to zero when the circuit breaker is turned off.

UNDERSTANDING ELECTRIC FAST TRANSIENTS

The EFT/B-100 is designed for fast transient testing in accordance with IEC 1000-4-4 and 801-4. These standards were developed to check equipment immunity to a real world EMC threat--transient bursts created by the relay disconnection of inductive loads. The test waveforms prescribed in the standards are an abstraction of the actual electrical phenemona that occur.

When a power relay opens an inductive load on a parallel-connected piece of electrical equipment (see fig. 4 & 5), the inductive surge results in a spark. A closer inspection of the spark shows that it is comprised of a burst of sparks, which start out quickly, at low amplitude, and increase in both voltage and spacing as the transient evolves. The burst consists of multiple sparks rather than a single one because, as the relay contacts open, the voltage needed to strike and sustain an arc increases. Thus the voltage imposed on the line consists of a series of pulses which rise as the voltage builds and fall as sparks occur. As the contacts open, the voltage needed to strike an arc increases. The burst of electrical pulses starts out at a relatively low voltage and high repetition rate. As the contacts open, the voltage of the pulse train increases and the repetition rate decreases (the interpulse period increases). The process ends when the contact spacing becomes wide enough that an arc can no longer be struck.

The details of this burst are highly variable and affected by many factors. Referring to figure 5, we see that the circuit components representing the switched inductance and the lumped characteristics of the parallel connected equipment and power lines (which are actually transmission lines) will clearly vary with the installation. Less obvious is the fact, that for a given switched circuit, the characteristics of the spark are highly dependent upon the detailed characteristics of the switching relay contacts such as the opening speed and open contact breakdown voltage. Sparks ranging from several hundred volts to over 4 kilovolts are seen, and the spark repetition rate can vary from several kilohertz to well over 100 kilohertz.

A measure of this variability is shown in Table 1, which shows experimental data taken on four circuits switching inductive loads. This data was supplied by IEC TC/77, which has responsibility for IEC 1000-4-4. The load time constant (L/R = 30 ms) was kept constant, but the relay type and operating current were varied. The most consistent characteristics of the pulses were their rapid rise time and narrow pulse width. Note the variability of the voltage level and frequency. Note also that, in all cases, the maximum pulse repetition frequency seen during the burst reached or exceeded 100 KHz.

The problem facing the writers of test standards designed to measure the immunity of equipment to fast transients was how to model the physical transient burst in a way which was could both be reproduced in test instrumentation and adequately simulate the severity of the actual event. In 1988, IEC TC/65, which is concerned with process equipment, published IEC 801-4. Based on the information available at that time, they decided to model the fast transient burst with a 15 ms train of unipolar pulses operating at 2.5 and 5 kHz repetition rates. The burst was repeated at 300 ms intervals. Later information proved that this initial model was inadequate.

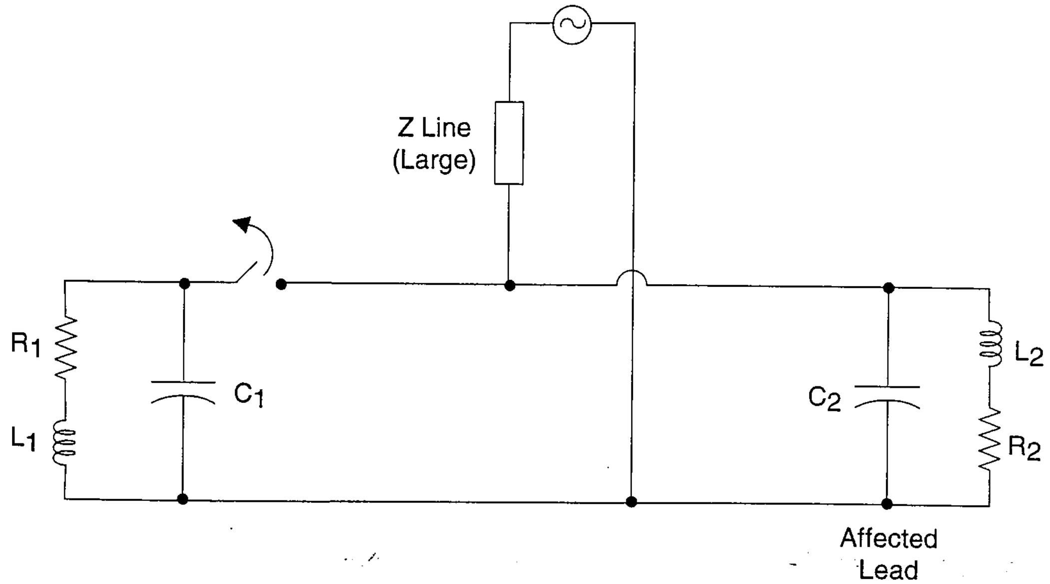


Figure 4

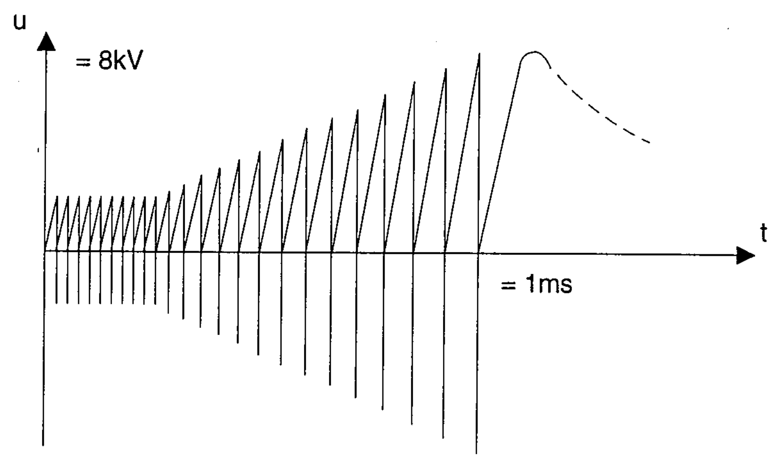


Figure 5

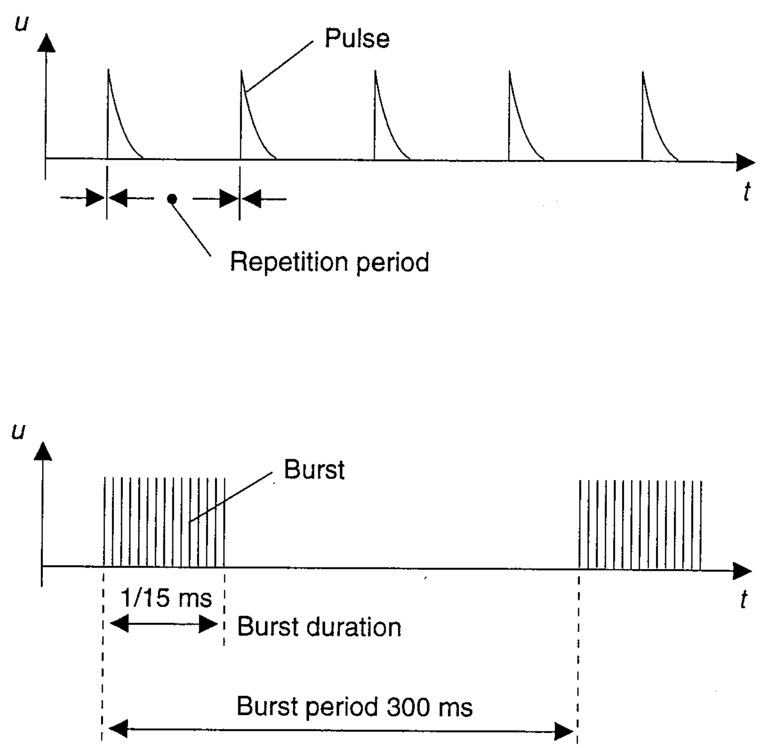

u
Pulse
t
Repetition period
u
Burst
t
1/15 ms
Burst duration
Burst period 300 ms

Figure 6

Parameters	Type of switching relay			
	Mercury wetted	Signalisation	Control (5 A)	Control (10 A)
Spikes amplitude (kV)	1 to 5	0,5 to 3	0,5 to 1,8	0,25 to 2,5
Rise time of the spike (ns)	<3	<3	<3	<3
Spikes duration (µs)	5 to 40	3,5 to 32	4 to 20	3,5 to 22
Time interval between spikes (µs)	10 to 80	7 to 65	8 to 40	7 to 45
Spikes repetition rate (kHz)	12 to 100	15 to 143	25 to 125	22 to 143
Number of spikes per burst	8	270	165	130
Burst length (ms)	0,2	2,2	2	1,7

Table 1

Experimenters found that equipment which was unaffected by transients of a given peak voltage and repetition rate would malfunction when if the pulse repetition rate was increased. It became obvious that higher pulse repetition rates were needed to realistically model the electrical fast transient phenemonon.

As the importance of electromagnetic compatibility became more widely recognized, the IEC gave responsibility for EMC standardization to its Technical Committee 77. TC/77 has responsibility for updating the IEC 801-x series of standards. Its recommendations for upgrading IEC 801-4 are not contained in the first edition of IEC 1000-4-4. As new research became available, it became obvious that IEC 801-4 needed updating in two respects:

- The pulse repetition rate needed to be greatly increased
- The dynamic impedance of the generator needed to be more tightly controlled

Revisions to IEC 1000-4-4 are being considered to make it a superset of IEC 801-4. Equipment tested in accordance with the recommendations of a revised IEC 1000-4-4 will also meet the requirements of the older standard. The IEC 1000-4-4 revision upgrades IEC 801-4 in the following manner:

- The maximum pulse repetition rate is raised from 5 kHz to 100 Khz. Tests must be performed at both repetition rates. At the added rate of 100 kHz, the burst width is reduced to 1 ms to keep the energy impressed on the equipment under test approximately constant.
- The generator dynamic impedance is much more tightly specified. IEC 801-4 specified the transient peak voltage, risetime, and pulse width into a 50 ohm load and specified the peak open circuit voltage. IEC 1000-4-4 goes one step further, and specifies the waveshape parameters into an open circuit as well as into a 50 ohm termination. This better defines the energy available to stress high impedance loads and eliminates variables due to differences in test generator design.
- The maximum distance between the generator and the equipment under test is shortened from 1.0 m to 0.3 m.

In effect, the revised IEC 1000-4-4 now working its way through committee is a superset of IEC 801-4.

TESTING FAST TRANSIENT IMMUNITY WITH THE EFT/B-100

This section contains some hints on performing electric fast transient tests with your EFT/B-100. We strongly suggest that you obtain and read the basic standards and any product specific standards that are available. At a minimum, you should be familiar with IEC 801-4 and IEC 1000-4-4. These are basic standards which describe general test methods and levels. Other relevant standards should also be consulted. These may include regional compliance requirements, such as those of the European Union, and product specific standards, such as the CISPR standards for information technology equipment.

A well thought-out and executed test plan will give confidence in the immunity measurements you make. The overall test procedure includes preliminary verification of equipment function, execution of the test, and evaluation of the results. The equipment to be tested should be placed in its normal operating mode (or modes, if multiple) during the test. The test plan should specify:

- the type of test (which standard or regulatory requirement)
- the EUT ports to be tested
- the representative operating conditions of the EUT
- the sequence of application of test voltage to the EUT's ports
- the auxiliary equipment supporting the EUT
- the test voltages applied to each port
- the duration and polarity (both polarities are required) of the bursts applied

The test report should note how the equipment performs during and after application of the transients. A basic performance breakdown of operation might use these classifications:

1. normal performance within specification

2. tempory degradation of performance or loss of function which is self-recoverable

3. tempory degradation of performance or loss of function which requires operator intervention or system reset

4. degradation or loss of function which is not recoverable due to damage to the hardware or software, or due to loss of data.

The plan will specify a series of tests. These will either be performed using the internal backfilter, or coupled to external equipment from the coaxial output. The procedures for testing in these modes are detailed below.

Although there are several ways of connecting the EFT/B-100 to the equipment to be tested, they follow a common theme. The basic idea is to couple the transients to the cables of the equipment under test via short connections.

For power leads, and other leads where the transient is conductively coupled in the field, a .033 uF capacitor is used to connect to individual leads. The capacitors provide both coupling from the generator and blocking of the voltages that may be present. For single phase EUTs using less than 15 A current, the transients can be delivered from the **EUT POWER OUT** conector. In this configuration, capacitors mounted inside the generator provide the coupling when selected by the front panel **COUPLING SELECTION** relays.

The alternative is to perform the coupling external to the generator. For power leads, this may be necessary because the EUT requires high current or utilizes three phase power. For each lead to be tested, connection is made from the front panel **COAX OUTPUT** connector using a .033 uF capacitor rated for "Y" connection. The connection between the generator and the surged lead should be short (<0.3 m).

To test the immunity of leads that experience electric fast transients through capacitive coupling rather than by the direct switching of a parallel-connected load, capacitive coupling is again used, but the connection is made through a smaller capacitance. Here too, the connection is made externally. The most common method of coupling will use a mechanically standardized distributed capacitance--i. e., the capacitive clamp described in the IEC standards. In special situations where the clamp is physically unsuitable, the clamp may be simulated by wrapping the cable to be tested with metal foil or tape, spaced 4 cm above the ground plane to approximate the distributed capacitance of the standardized camp. Another method, which may yield somewhat different results, is to use a discrete capacitance of 100 pf to approximate the effect of the clamp on individual leads. In all cases, the lead length between the generator and the external point of attachment should be kept short, and a groundplane (minimum 1 m^2) should be used to stabilize the connection characteristics.

INJECTING TRANSIENTS VIA THE EUT POWER OUT CONNECTOR

This method of testing injects transients into the AC power of attached equipment. It simulates the transients that are conducted along the power line to equipment when parallel inductive loads are disconnected from the line. When this test is performed, the internal backfilter decouples the transients from the power line, directing all transient energy to the equipment under test. For both table top and floor mounted equipment, a ground plane should be employed. The length of wire between the EUT and the EFT/B-100 should be as short as possible to minimize distortion of the fast transient waveshape. IEC 801-4 recommends that this length be less than 1 meter; the revised standard, IEC 1000-4-4 recommends that the lead length be shortened to under 0.3 meters. Follow these steps:

1. Connect the EFT/B-100 to AC power using the supplied power cord. Generator power is connected via the **AC POWER** connector.

2. Connect the power for the equipment under test (EUT) to the desired AC power source. Depending on the needs of the equipment under test, this may be the same power source

as that used for powering the generator, or a different voltage level. EUT power is connected to the **EUT POWER IN** connector.

3. Turn on the **EUT POWER SWITCH** circuit breaker to make power available to the equipment under test.

4. Turn on the equipment to be tested. To fully assess the immunity of a piece of equipment, surges should be delivered in all relevant operating states. This may necessitate the operation of a customized program for testing, or it may require retesting in various operational modes.

5. Turn on the EFT/B-100.

6. Set the **CONTROL OPTION** switch to MANUAL for operation from the front panel.

7. Adust the **VOLTAGE ADJUST** control for the desired open-circuit transient amplitude.

8. Select the desired frequency by pushing one of the four **FREQUENCY** switches.

9. Select the **COUPLING SELECTION** relays. Typically, the EUT power leads will be surged individually and together. (e.g., **L**, **N**, and **PE** sequentially, and then **L/N/PE** together).

10. Select the polarity for the test. Depressing the **POLARITY** switch toggles the polarity between positive and negative.

11. Decide whether or not to use the **TIMER OVERRIDE.** If the TIMER OVERRIDE LED is lit, the unit will run until it is stopped manually. If the TIMER OVERRIDE LED is unlit, the unit will automatically stop running after approximately 15 minutes, although it can be stopped sooner by depressing the **STOP** switch.

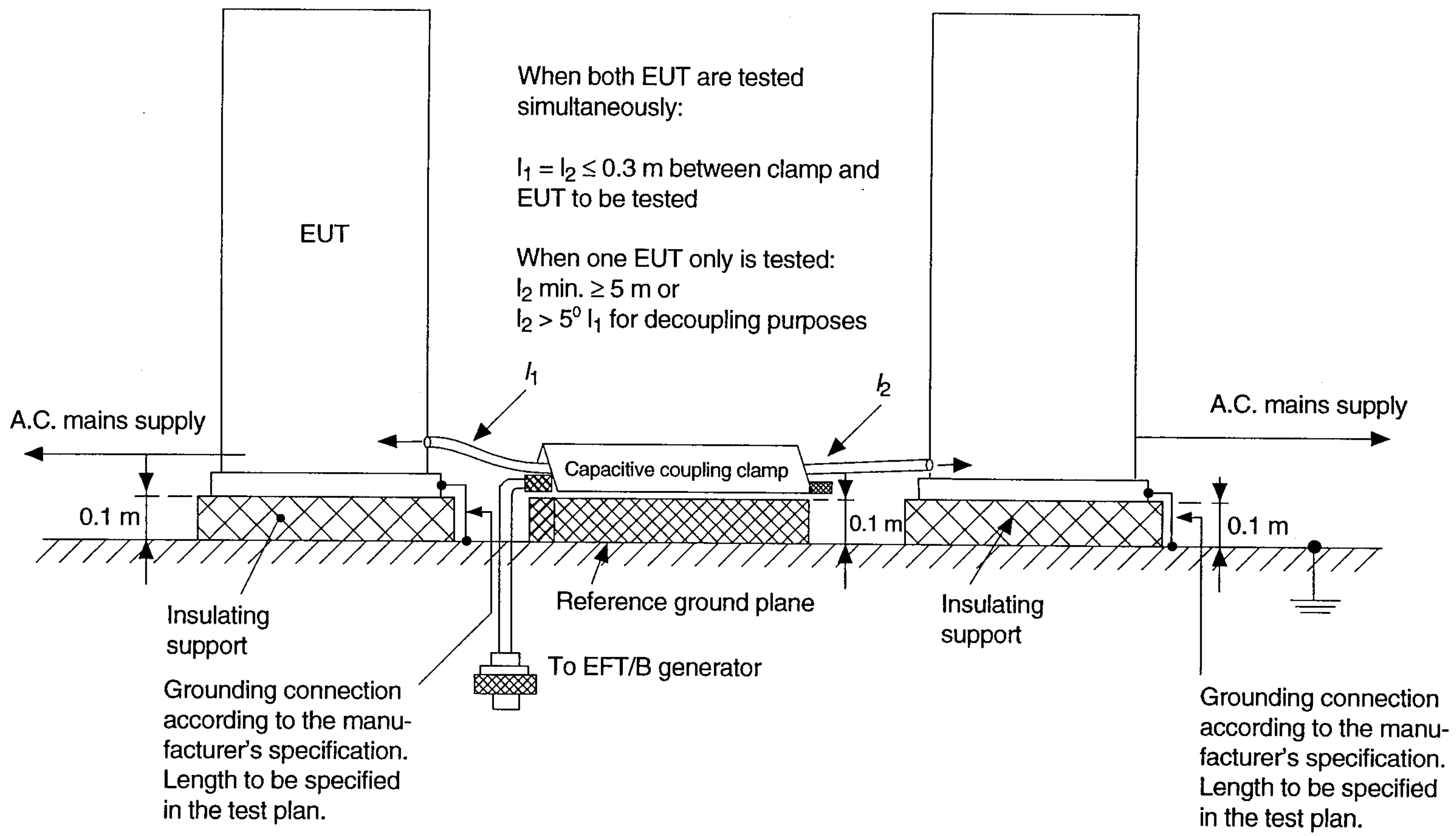
12. Start the test by depressing the **RUN** switch.

13. Stop the test after the desired period by depressing the **STOP** switch.

The test should be repeated as necessary to include both polarities of transient, all line leads, and all relevant operating modes. If desired, an oscilliscope may be connected to the **OUTPUT MONITOR** connector to verify that transients are being delivered.

USING THE CAPACITIVE CLAMP

For most signal, control, and DC supply lines, the capacitive clamp may be used to test for immunity to electrical fast transients. This mirrors the way that transients are often coupled onto these leads in field applications. It is not uncommon for these leads to be conduited with or dressed near AC power lines on which electric fast transients occur. The capacitive clamp



EUT
When both EUT are tested simultaneously:
l1 = l2 ≤ 0.3 m between clamp and EUT to be tested
When one EUT only is tested:
l2 min. ≥ 5 m or
l2 > 5⁰ l1 for decoupling purposes
l1
l2
A.C. mains supply
A.C. mains supply
Capacitive coupling clamp
0.1 m
0.1 m
0.1 m
Insulating support
Reference ground plane
Insulating support
To EFT/B generator
Grounding connection according to the manufacturer's specification. Length to be specified in the test plan.
Grounding connection according to the manufacturer's specification. Length to be specified in the test plan.

Figure 7

provides a realistic simulation of the capacitive coupling characteristic of these configurations.

When using the capacitive clamp, the signal is taken from the EFT/B-100's **COAX OUTPUT** connector and connected to the clamp's coaxial connectors.

The flat ground conductor of the clamp is placed on the test groundplane and the triangular center flange is closed over the cables to be tested. The distance between the clamp and the EUT should be short (less than 0.3 meters). If the other end of the cable connects auxiliary equipment that is not considered part of the test, the auxiliary equipment should be relatively "far" away so the transients are coupled primarily to the EUT. "Far" is defined as 5 meters or at least five times the distance to the EUT in IEC 1000-4-4. If the units on both sides of the cable are considered part of the EUT, then the cable length between the clamp and both units should be kept short. Figure 7 sketches this setup.

To use the capacitive clamp, use this procedure:

1. Connect the EFT/B-100 to AC power using the supplied power cord. Generator power is connected via the **AC POWER** connector.

2. Set up the equipment to be tested and install the capacitive clamp on the test site groundplane. The flat surface of the clamp should be in electrical contact with the groundplane.

3. Connect the capacitive clamp to the **COAX OUTPUT** connector using 50 ohm coaxial cable.

4. Power up the EUT and place it in the desired operating mode.

5. Turn on the EFT/B-100.

6. Adjust the **VOLTAGE ADJUST** control for the desired voltage.

7. Set the frequency by depressing one of the four **FREQUENCY** switches.

8. Select the **COAX** relay from the **COUPLING SELECTION** group.

9. Select the test polarity.

10. Decide whether or not to employ **TIMER OVERRIDE.**

11. Start the test with the **RUN** switch.

12. End the test with the **STOP** switch.

As mentioned above, alternatives to the capacitive clamp include the use of a foil wrapping, or the use of a discrete 100 pF coupling capacitor.

INJECTING LINE TRANSIENTS WITH EXTERNAL COUPLING

When connections to power leads are made externally, coupling is made via .033 uF capacitors. This may take two forms. Either a packaged, shielded external backfilter with the necessary rating may be employed, in which case the capacitors will be internal to it, or the attachment may be made externally. Obviously, all power connections should be made carefully and made electrically safe.

Operation using an external backfilter or external capacitors is similar to operation with the capacitive clamp. The generator is set to couple transients to the coaxial output connection with the **COAX** coupling switch, operating parameters are set, and the unit is started. Remember that with external power leads, coupling changes must be made by manually changing the leads the generator is connected to.

SPECIFICATIONS

Power:	120/240 VAC, 50/60 Hz, user selectable, 50 Watts
Fuse:	1 A @ 120 volts; 0.5 A @ 240 V
EUT Power:	120/240 VAC, 15 A maximum through internal backfilter. Front panel circuit breaker.
Output Coupling:	Front panel selectable between coaxial and individual leads of internal backfilter.
Output Pulse:	per IEC 801-4 and IEC10004-4
Amplitude:	0 - 4 kV open circuit, 0 - 2 kV into 50 ohms, continuously adjustable. Metered accuracy better than 10%
Rise Time:	5 ns +/- 30%
50% Pulse Width:	50 ns +/- 30%
Pulse Frequency:	2.5, 5, 10, and 100 kHz, switch selectable (Continuously adjustable with remote option)
Burst Repetition Period:	300 ms
Burst Width:	15 ms for 2.5 and 5 kHz 1 ms for 10 and 100 kHz

LIMITED WARRANTY

Compliance Design Incorporated (CDI) warrants that its products, at the time of delivery, are free from defects of workmanship and material under normal use and service. CDI reserves a right, at its exclusive option, to replace or repair, in its own factory, any articles which are disclosed to CDI's satisfaction to be defective within one year of delivery. Transportation charges to CDI's factory shall be prepaid by the buyer.

THIS WARRANTY IS EXPRESSED IN LIEU OF ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING THE WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE, MERCHANTABILITY AND/OR ANY AND ALL OBLIGATIONS OR LIABILITIES. CDI NEITHER ASSUMES NOR AUTHORIZES ANY OTHER PERSON TO ACT AS AGENT FOR CDI OR TO ASSUME ANY OTHER LIABILITIES IN CONNECTION WITH DELIVERY OF THIS PRODUCT.

This warranty is limited to 90 days on out-of-warranty repairs and shall not apply to any products which have been repaired or altered by the buyer, or which have been misused or subjected to neglect or accident.