POWER-LINE DISTURBANCES AND HOW TO ELIMINATE THEM

As the electronics industry continues to offer innovative products and increased software capability, the need to identify and resolve power disturbance problems becomes greater than ever.

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POWER DISTURBANCES

Power disturbances have numerous names or identities associated with their specific definition. Before discussing each, it is useful to take a look at the power originator (i.e., the power company) which is governed by law to provide power within specified limits for a given region. It is important to note here that the power companies or utilities reliably provide power within the specified guidelines, but the need for "clean" power to the microprocessor-based industry makes these guidelines inadequate.

"Clean" power is a buzz word in the industry, indicating a stable, nominal ac voltage, and the elimination of line noise or transients.

For purposes of this article, power disturbances will be divided into two categories.

Transverse Mode Noise is an event or disturbance which occurs between two lines of a power source (i.e., between two hot lines or between hot and neutral). Nominal ac power is an example of a transverse mode signal.

Common Mode Noise is an event or disturbance that occurs between either line and the ground, that is, where no signal is expected in an isolated system. (See Figure 1.)

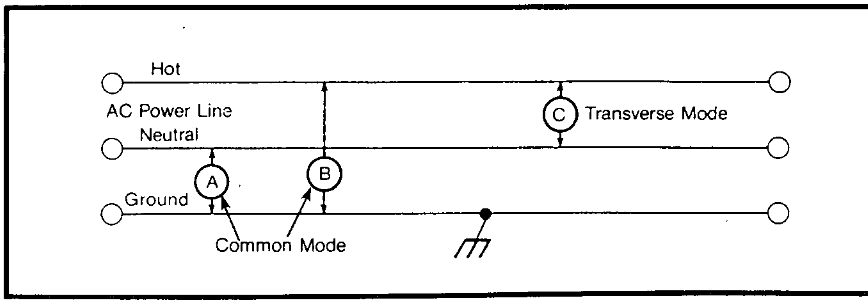


Figure 1. Transverse/Common Mode Noise.

Both of these categories can be further subdivided, depending upon the length of time the disturbance lasts. Figure 2 shows this breakdown in a condensed diagram. The transverse mode events include:

Impulse or Transient. These are very short duration (less than a millisecond) occurrences that add or subtract from the sine wave. The major problem with the transient is its frequency and magnitude. It is not unusual to have nanosecond range transients with magnitudes of 400 and 500 volts on the ac line. A closer look shows that these transients can occur positively or negatively, and merely add or subtract energy from the sine wave. (See Figure 3.) Typical causes include the firing of SCRs, welders, igniters, switching power supplies, electrical storms, utility switching for load or power factor correction, and fault clearing.

Sags & Surges. These are multi-cycle power variations of 10% or more. Typical causes include load switching on/off, such as air conditioners, disk drive, machine shops, transformers, and ovens.

Drop-out. This is a total loss of voltage for a relatively short period of time, such as a millisecond. Typical causes include momentary line fault and utility switching operations.

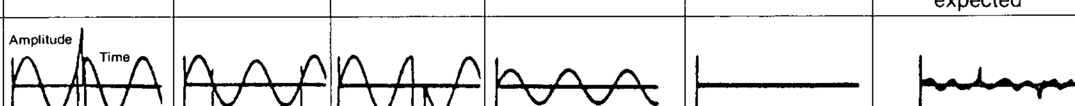
Event Category		Transverse-mode Events				Common-mode Event
Problem	Transient or Impulse	Sag / Surge	Drop-out	Hi / Low Line	Blackout	Common-mode Noise
Definition	Short duration transient in voltage	Multi-cycle variation in voltage amplitude	Total loss of voltage for part of the sinewave	Voltage amplitude long-term average variation	Total loss of electrical power for an extended period of time	Voltage signal occurring between either line and ground where no signal is expected
Characteristics	 Less than 10^{-3} seconds	10^{-3} to 1-second	10^{-3} to 1-second	Greater than 1-second		

Figure 2. Categorizations of Transverse-mode Events and Common-mode Events.

HI/LO Line. This is a long-term (several seconds to several hours) voltage average variation. Causes include brownouts and other cutbacks due to shortages, daily demand fluctuation, and long-line regulation problems.

Blackout. This is a total loss of electrical power for an extended period of time. Causes could be ice storms, catastrophic system faults, highway accidents, and transformer burnout.

The common mode events break down into one category.

Common mode noise as previously noted, is a high frequency voltage signal occurring between either line and ground, where no signal is expected. Causes could be lightning, impulse noise, grounding faults, poor grounding practices, radio transmitters, machine tools, and time clocks.

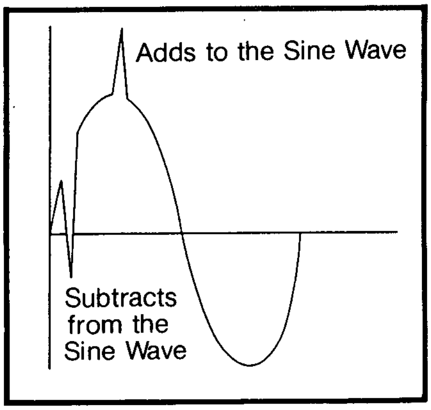


Figure 3. Impulses or Transients.

"POWER DISTURBANCE EFFECTS" ON POWER SUPPLIES

Virtually every piece of electronic equipment in the world today is powered from a dc source. This could be either a battery or a power supply. Most of this electronic equipment requires a well filtered and well regulated dc source.

How Voltage and Noise Variations Affect Power Supplies. In principle, the "ideal" power supply

provides constant output voltage regardless of variations on the input;

provides constant load current;

runs at an ambient temperature;

produces an output impedance of zero for all frequencies;

has a 100% conversion efficiency; and

produces no ripple or noise on the output voltage.

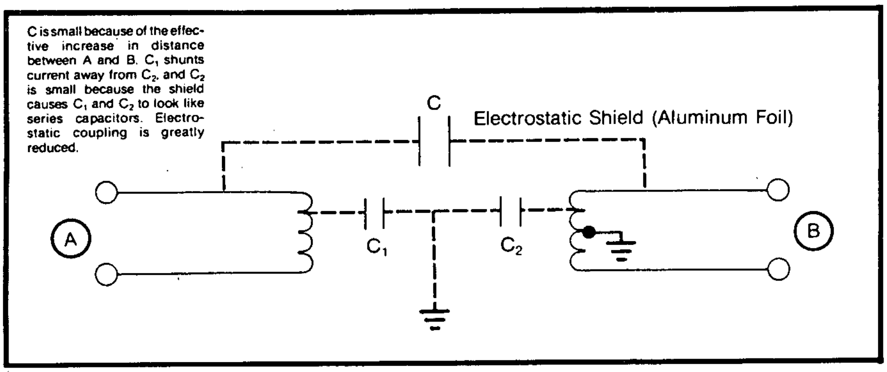


Figure 4. Isolation Transformer.

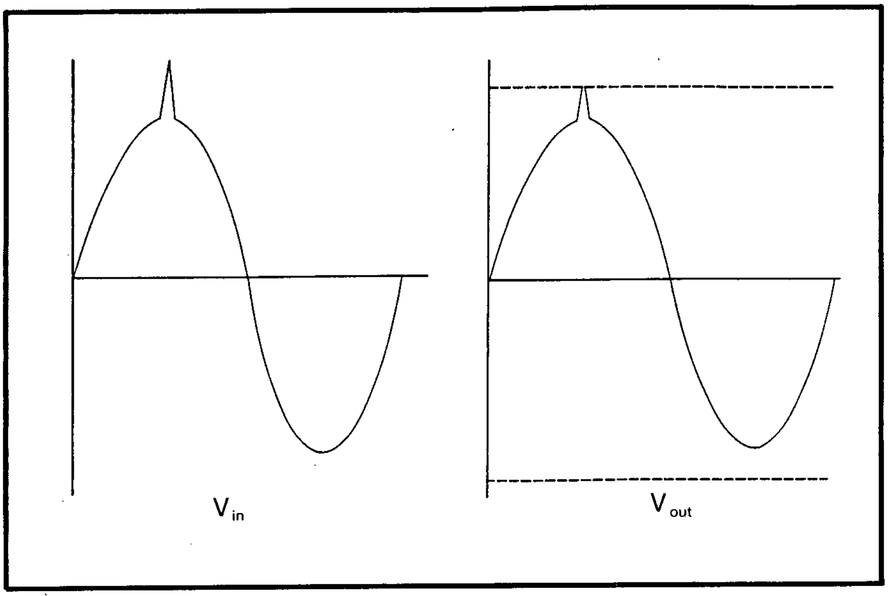


Figure 5. M.O.V. Response.

A typical linear power supply is approximately 40 to 55% efficient and a switching power supply is approximately 60 to 80% efficient. The typical computer power supply is capable of handling voltage variation of 6 to 8% from nominal, and the power company is typically regulated to hold voltage within 5% of nominal. This is the voltage to the building. However, the line drops as the power is distributed around a plant. Also, any voltage fluctuations could easily give an input range to a system of ±15% from nominal. This deviation can cause overheating of the supply, and, consequently, a decrease in its power. Or, it can pass higher current to the dc bus. In either case, unless they are considered in the original design, wide range voltage fluctuations are not beneficial to the overall life and maintenance of a power supply.

Transverse Mode and Common Mode Noise. Transverse mode noise can typically run from nanosecond to millisecond range and appear on the power-line feeding the supply. If these transients exceed the maximum rated input voltage and/or are fast enough, they will pass directly into the dc bus. There, they can destroy or weaken printed circuit board components, including the microprocessor.

Common mode noise is also of extremely high frequency, and, typically, is not suppressed within the power supply design. Consequently, it can weaken components and cause

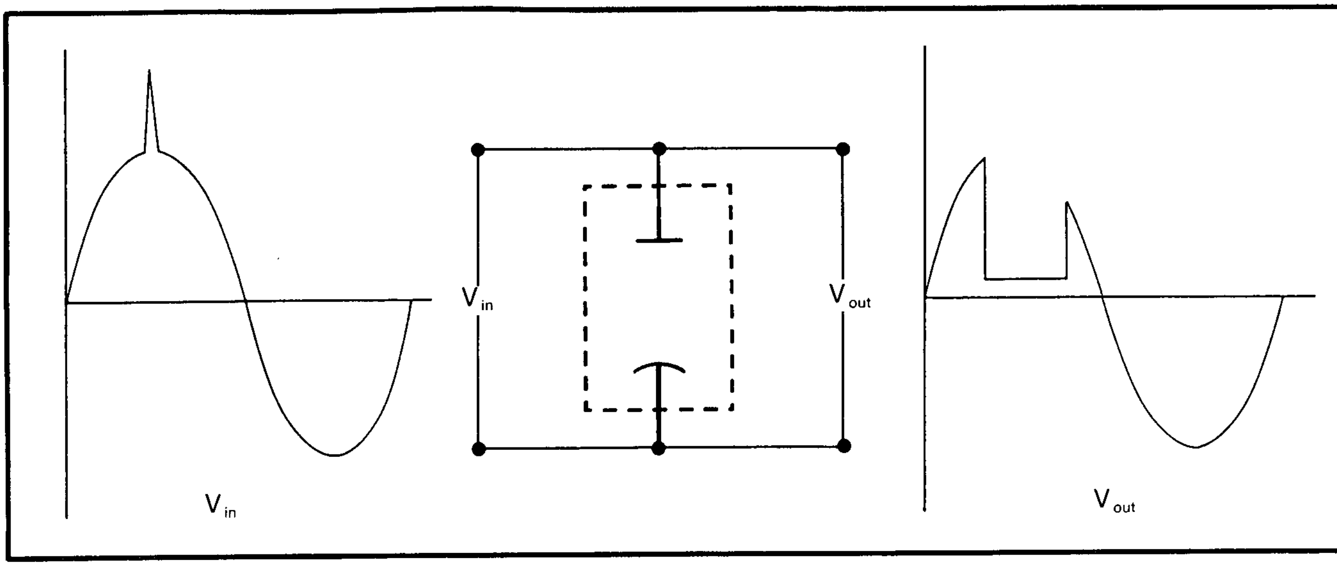


Figure 6. Gas Tube Suppressor.

premature failure. Some power supplies employ a Faraday shield to increase isolation, which can help with common mode noise.

Dropouts and Blackouts. Besides voltage variations and line noise, another major cause of computer shutdowns or damage are dropouts and blackouts. A power supply must be able to react within ¼ cycle or less to these problems and either revert to a backup power source or undergo an orderly shutdown process.

SOLVING POWER PROBLEMS

The host of available solutions cover a wide range of technologies that carry both advantages and disadvantages. It is important for the equipment testing personnel to understand the specific power problem or problems involved, so that the optimum solution is selected.

The various types of power disturbance eliminators include the following.

Isolation Transformers. (See Figure 4.) By adequately separating the primary from the secondary in these transformers, electrostatic capacitive coupling is effectively reduced. This all but eliminates common mode noise from entering the load. Typical isolation transformers can attenuate common mode noise from 60dB up to 140dB, depending on the type of shielding used. The main use for this type of design would be the elimination of common mode noise and grounding. An isolation transformer does not provide transverse mode attenuation, nor does it provide voltage regulation.

Transient Suppressors. These include: M.O.V.s (Metal Oxide Varistors); Gas Tubes; and Low Pass Filters. Each deals with the transverse mode, but handles the transient differently by design.

The M.O.V. effectively puts rails on the sine wave. (See Figure 5.) It will dissipate transients outside the rail, but the energy within the rails remains. As long as this remaining energy is small enough, it will not be dangerous to the power supply. However, M.O.V.s have a relative life associated to them and can withstand only so many transients before they weaken and become ineffective.

The gas tube will completely eliminate the transient, but will also take energy out of the sine wave. (See Figure 6.) They are better used early on in the power-line to handle lightning or other high energy transients.

The low pass filter utilizes a transformer and a series of resistor capacitors to effectively attenuate the transient anywhere on the sine wave. (See Figure 7.) Attenuation of 40dB

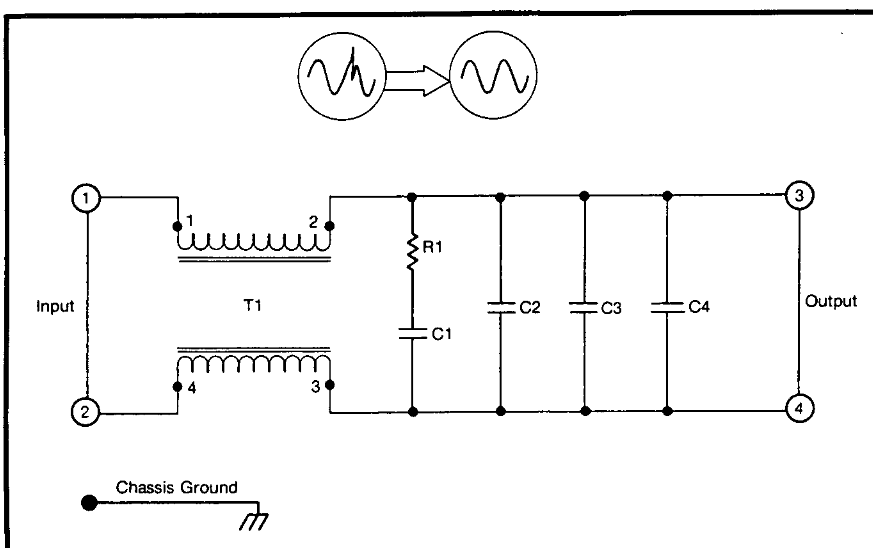


Figure 7. Low Pass Filter.

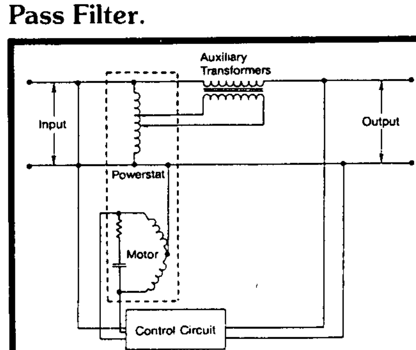


Figure 8. Electromechanical Regulator.

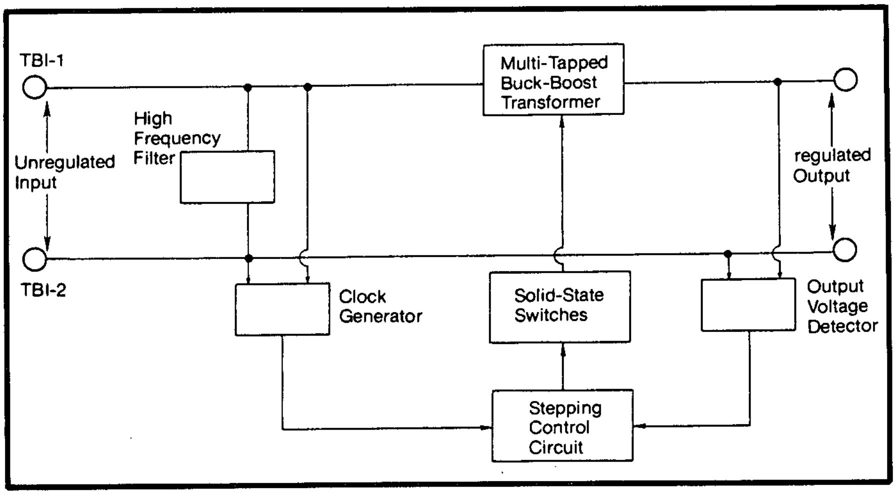


Figure 9. Switching Regulator.

to 60dB is normal for this type of design. The advantage of this design is attenuation of all transients (transverse mode) without affecting the sine wave.

The main use of these transient suppressors is for transverse mode noise elimination. They do not provide common mode noise attenuation, nor do they regulate voltage.

Voltage Regulators. Three basic designs are prominent in regulators. They are: electromechanical regulators; switching regulators (solid state); and ferroresonant regulators.

The electromechanical version utilizes a solid-state detector to monitor the output voltage, a motor-driven variable transformer, and a buck-boost fixed ratio transformer. (See Figure 8.) When the output voltage deviates from the preset nominal, the detector produces an error signal which causes the variable transformer drive motor to actuate and return the voltage to the desired level. The advantage of this design is wide-range inputs (±15% and higher) that can be regulated to very accurate outputs (±1% or less). They run efficiently, but may react too slowly to voltage variations. They are very useful for large computer systems.

In the switching regulator, solid-state switches are used in switching the buck-boost taps. (See Figure 9.) The control unit for the switching action uses two input signals. The signal from the output voltage detector is used to determine whether the monitored output is within regulation, or if it requires correction. The second signal is from the clock generator which ensures that each step occurs at zero waveform crossing. A capacitive filter is connected across the input to minimize high frequency noise from the line. This design provides very good regulation (usually about ±4%) and is relatively high in efficiency (approximately 95%). It also handles in-rush currents very well without passing them on to the load. It is important to assure that the design incorporates SCRs that fire at zero waveform crossing; otherwise, transients could be produced by the regulator and fed to the load.

Ferroresonant transformers are similar to conventional power transformers in appearance, but produce a constant voltage output even though the input line voltage fluctuates. (See Figure 10.) The ferroresonant transformer is designed to operate in saturation. Its regulating characteristics depend on two things: the size of the air gap in the center section, and the relationship between the inductance and the capacitance. When ac current begins to flow through the primary winding, the resulting flux produces a secondary voltage. Because of its air gap, the center core section has high reluctance, and the flux coupling is principally through the outer core sections. At this point, the secondary voltage is determined mainly by the transformer turns ratio. The regulation characteristics for ferroresonant units are very good - approximately ±3% with ±15 to 20% input. The efficiency is not as good as other units and runs at approximately 80% at full load. Also, since they are current-limited by design, ferroresonants do not have good in-rush current handling capabilities and operate more efficiently at full load rate.

Voltage regulators as described above strictly regulate the output voltage to a given nominal. They do not attenuate line noise.

Power Conditioners. These systems combine the characteristics of the transient suppressor, isolation transformer, and voltage regulator to provide both regulation and noise rejection. (See Figures 11 and 12.)

Ferroresonant-type power conditioners provide good regulation, maintenance (no moving parts), and noise rejection, but have problems with efficiency (about 80%), and in-rush current.

Tap switching power conditioners provide good regulation, high efficiency, and handling of in-rush current, but have problems with electronics (could be maintenance suspect), and SCRs (could add line noise).

Electromechanical power conditioners provide good regulation - ±1%, overload capability, and efficiency, but have problems with reaction to voltage variation com-

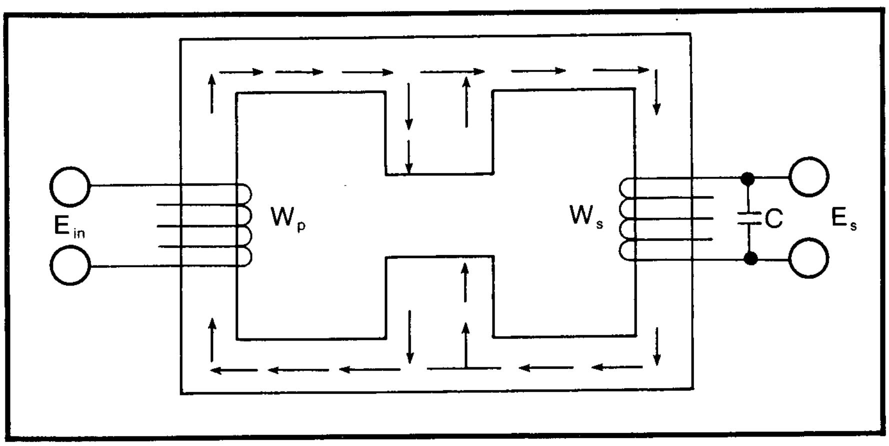


Figure 10. Ferroresonant Transformer.

pared to tap switches and ferroresonant conditioners - relatively slow, and moving parts - maintenance becomes an issue.

Assessing the needs of a specific installation, power supply design, or manufacturers' requirements will give the end user the best means of choosing the right piece of equipment.

UPS Systems. A UPS system is any source that protects a critical load, such as a computer, a communications network, or a control system from blackout or brownout conditions. The need for a UPS system is determined by a number of considerations, but, generally, any machine, instrument, electrical or electronic system or computer installation that could be operationally impaired because of unpredictable power-line changes or failures needs a UPS system. Actually, the need for a UPS system will always be determined by comparing the expense, danger or inconvenience caused by unpredicted power failures to the cost of installing and maintaining the UPS system.

The three basic types of UPS are:

Engine Generator. This equipment consists of a supply of stored energy, fuel oil, gasoline, propane, and a prime mover generator set. The system may be run continuously, creating, in effect, a local utility; or it may be held in a standby mode, ready to supply power on a one- to 15-minute start-up basis. Such systems are mandatory for critical areas in health-care facilities where life support systems cannot be compromised. For absolute continuity of service, UPS may be used to supply energy to critical load for the one- to 15-minute period required to bring a standby engine generator on-line.

Electronic Uninterruptible Power Supplies (UPS). These systems consist of an ac-to-dc-to-ac electronic package with storage battery backup for the intermediate dc bus. When properly designed, this equipment can be quite effective in protecting against all of the noise sources listed, except blackout. The storage battery size will determine how far into the blackout energy continuity to the load can be maintained. The UPS can easily be configured to bridge the energy gap while an engine generator is brought on-line.

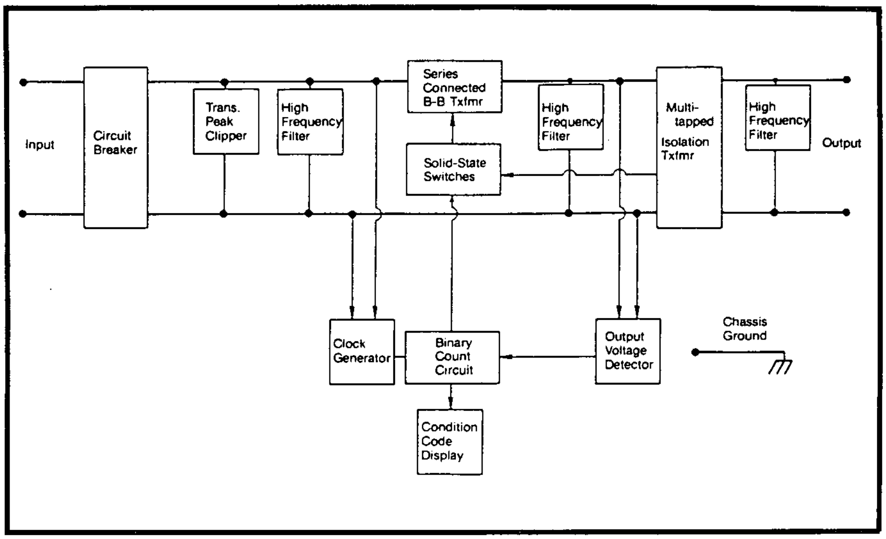


Figure 11. Circuit Diagram of Power Conditioner System.

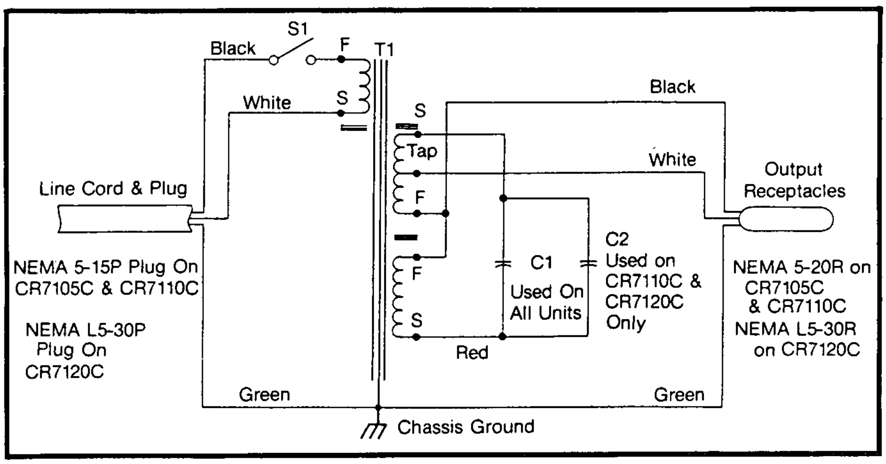


Figure 12. Power Conditioner System.

Motor Generator. This system usually consists of a three-phase electric motor, which is coupled to a generator that supplies the critical load power. This system can effectively isolate the load from all the noise sources listed except blackout. The equipment will carry through dropouts of 200 to 500 milliseconds, and can provide a delay of blackout problems long enough for critical loads to be signalled and brought to an orderly shutdown with minimum loss of performance or damage.

Cost is a significant factor when selecting a UPS system, but these systems cover the large KVA requirements. At the lower end are off-line types of UPSs which provide battery back-up for 10 minutes or more. The important features to note with this approach are:

Transfer time. In most cases, 4 to 8 milliseconds is the maximum that can be accepted by the power supply.

Voltage output during battery operation. A sine wave is necessary to preclude a distorted square wave output, which is usually not the most suitable for a power supply.

Power conditioning during normal line operation. Full protection is needed for normal line generation.

In summary, the marketplace offers a host of solutions for power-line problems. What is important is that the end user understands the importance of this power protection and obtains the best course of action. Economics and the power environment will play a major role in this decision. The computer manufacturer is most helpful when the exact power needs for his equipment, including voltage input and noise acceptance capability, are specified. ■