A MICROSURGE METER FOR
ELECTRICAL POLLUTION RESEARCH

by

Martin Graham

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ELECTRONICS RESEARCH LABORATORY

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A MICROSURGE METER FOR ELECTRICAL POLLUTION RESEARCH

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ABSTRACT

An inexpensive and simple to use instrument called a Microsurge Meter is described. It produces a digital reading related to how harmful the electrical pollution is to humans in that microenvironment.

A MICROSURGE METER FOR ELECTRICAL POLLUTION RESEARCH

Electrical pollution is an environmental problem in which the environment of concern is the space within a few feet of the human. Harmful currents flow through humans without humans making direct contact with conductors. The distance between humans and wires in homes is small compared to the distance between humans and the wires of the electric utility distribution systems. Since an electric field decreases rapidly with the distance from the conductor, measurement and mitigation should concentrate on the immediate environment, which might be referred to as a microenvironment.

Many homes have employed the mitigation techniques described in "Mitigation of Electrical Pollution in the Home" (Appendix A). Many of the occupants of these homes have reported a reduction of the symptoms described in "A Ubiquitous Pollutant" (Appendix B). The improvement usually occurred within days after the installation of the capacitors, which reduce the high frequency electric fields associated with the wiring in their homes without reducing the 60 Hz electric fields.

High frequency transients are often referred to as surges, and information on them and their harmful effect on electrical equipment, but not on humans, is on utility web sites (Appendix C). Information on the source of these surges and how to mitigate them is also on utility web sites (Appendix D).

The instrument described in "A Ubiquitous Pollutant" measures the heating effect of the transients. The effects of transient electrical fields on humans are related more to their peak amplitude and is cumulative. One large transient can convert a fibrillating heart to normal rhythm in seconds. Many small transients can have more subtle effects which develop over a period of time, and can be life threatening.

A combined filter and peak detector designed to measure the level of pollution is shown in Appendix E. It should cost less than $40. The total cost of the filter and peak detector together with the associated D.C. Voltmeter should be less than $90. This instrument can be used to determine the level of pollution at electrical outlets in a home and whether the pollution source is in the home or in a neighbor's home or in the electrical utility. When all the electrical loads in a home are turned off the pollution reading is due to sources outside the home. Steady readings of over 400 milivolts D.C. should be a cause for concern.

An individual can do research in electrical pollution be observing the relation of the electrical pollution level with how they feel. The observation is most meaningful when a large change in the electrical pollution level occurs over a short period of time. An individual can reduce the electrical pollution from a high level to a low level using the techniques described in "Mitigating Electrical Pollution in the Home." Some diabetic individuals experience a change in their monitored blood glucose levels when the electrical pollution level changes, and this is a recognized clinical measurement.

THE MITIGATION OF ELECTRICAL POLLUTION IN THE HOME

The electrical pollution considered in this report is electrostatic fields that vary rapidly in a random or noiselike pattern. When Guglielmo Marconi transmitted wireless signals from Polphu, England to St. John's, New Foundland on December 12, 1901 he used a spark transmitter that generated fields of this type. The antenna and the ground were connected to the spark gap. The wireless signals used today are much more orderly, since this is the basic way to enable multiple communication channels that share a common medium [1]. These modern signals have sinusoidal waveforms that are similar to those in the electrical distribution systems. However, there are millions of transmitters in the electrical power system that are the equivalent of Marconi's transmitter, and the power distribution wires are the antennas and grounds that couple these noiselike signals to humans. An inexpensive hand held AM radio receiver will detect these signals. Tune the receiver to the lowest frequency on the dial (about 500 kilohertz) which is below the lowest frequency broadcast station, turn up the volume, and you will hear a noise. As the receiver comes closer to a transmitter, the noise becomes louder. Try it near dimmer switches at various settings, personal computer displays and keyboards, fax machines, microwave ovens, electronic telephones, high efficiency fluorescent lamp bulbs, video tape recorders, and hand held hair dryers. The effects on humans depend on the path the currents produced by these fields takes through the humans, on the sensitivity of the individual, and on the amplitude, waveform, and duration of the fields. There is strong evidence that these currents may cause cancers, but this report is concerned with reducing the symptoms that humans can directly observe in themselves, such as poor short-term memory, chronic fatigue, depression, nausea, and rashes.

The Marconi Transmitters may be there because of the customer, or they may be there because of the utility. Some of the transmitters belonging to the customer are

- Hair dryers
- Dimmer switches
- Electronic transformers in low voltage halogen reading lamps
- Loose electrical connections
- High efficiency electronic systems

Some transmitters belonging to the utility are

- Switches controlling the power factor correction capacitors
- Tap switches on transformers for voltage regulation
- Deteriorated wires and connectors

There are transmitters which belong to other customers that are connected by the utility distribution system to your house. One such case is the strobe lights located on radio towers for aircraft warning purposes. The signals generated by these transmitters can travel considerable distances. The electric fields produced by these noise voltages between the power wires in a home can be reduced by lowering the impedance between the wires. Connecting a large capacitance between the wires has been effective in many cases in reducing the symptoms experienced by the occupants of the home. The capacitances used in these tests were about 200 microfarads across each 120 Volt circuit in the usual 240 Volt utility distribution system. In most cases these were installed at the main distribution in the home by a licensed electrician. Appendix A describes how an individual can evaluate the effectiveness of this mitigation technique on their symptoms.

APPENDIX A

An individual can install a capacitor across the 120 Volt circuit by electrically connecting it to a plug that is inserted into a 120 Volt electrical outlet, which is the type used in homes for appliances such as lamps, television sets, toasters, etc. A good arrangements for individuals is to plug in ten to twenty 20 microfarad motor run AC capacitors into a number of different outlets. Suppliers of these capacitors can be found in the telephone yellow pages under electric motors and/or electrical supplies. The newer A.C. dry film capacitors in epoxy cases are better for this use by nonprofessionals than the older style oil filled capacitors in metal cases, but either will mitigate the pollution. The mitigation is somewhat more effective if the capacitors are plugged into outlets used for appliances that individuals are close to for extended periods of time, such as reading lamps, radios and television receivers, and kitchen appliances.

Particular attention should be paid to safety.

- There should be no exposed electrical conductors.
- The components should be in a enclosure that prevents children from tampering with the device.
- Whenever a capacitor is disconnected from the outlet, it may have energy stored in it which will remain there for hours. A 27 kilohm 2 watt resistor permanently connected directly across the 20-microfarad capacitor will remove the stored energy within a few seconds without wasting appreciable power while the capacitor is connected to the outlet. Some sparking may occur at the plug when the capacitor is connected. This is normal.

REFERENCE

[1] Sungook Hong, *Wireless (from Marconi's black-box to the audion)*, The MIT Press, Massachusetts Institute of Technology, Cambridge, MA 02142, 2001.

APPENDIX B

A UBIQUITOUS POLLUTANT

by

Martin Graham

Memorandum No. UCB/ERL M00/55

28 October 2000

ELECTRONICS RESEARCH LABORATORY

College of Engineering
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A Ubiquitous Pollutant

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ABSTRACT

High frequency voltages present on the electrical power wires in homes, offices, schools and factories should be considered a potential pollutant. An inexpensive and simple to use instrument is described for measuring these voltages.

The letter of May 4, 1999 by Kenneth Olden which accompanied the *NIEHS Report on Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields*[1] contains the following paragraph:

> The lack of connection between the human data and the experimental data (animal and mechanistic) severely complicates the interpretation of these results. The human data are in the "right" species, are tied to "real life" exposures and show some consistency that is difficult to ignore. This assessment is tempered by the observation that given the weak magnitude of these increased risks, some other factor or common source of error could explain these findings. However, no consistent explanation other than exposure to ELF-EMF has been identified.

This report suggests that the "some other factor" is high frequency currents, i.e., much higher frequency than the power line frequency. High frequency voltage can cause currents to flow in humans by direct contact, or by capacitive coupling. The effects on humans will depend on the magnitude, waveform, duration, and path taken through the body. The voltage causing these currents should be considered a pollutant.

The presence of a pollutant is often obscured by the presence of much larger quantities of non-pollutants. Low level high frequency voltages are often obscured by the large power frequency voltages, but low level high frequency voltage compared to the power line voltage does not imply that they do not cause detrimental health effects in humans.

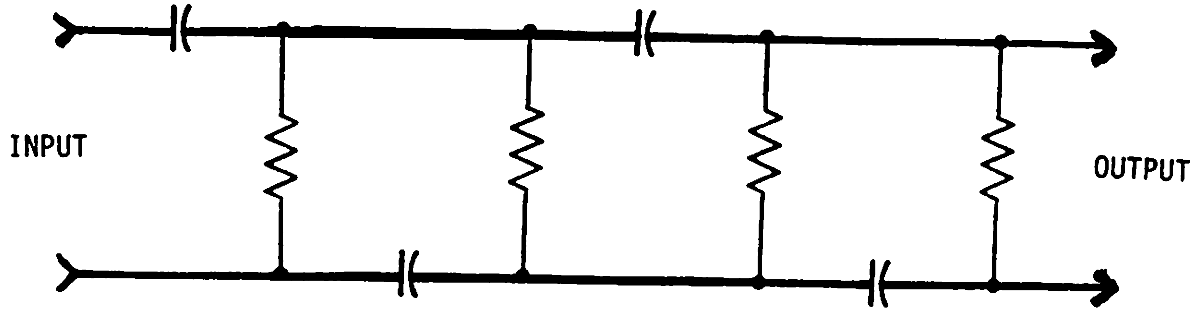
It is always a problem as to where to measure a pollutant such as high frequency electric fields. An instrument has been developed to do a very simple measurement. The measured voltage is that present at the standard household electrical outlet. A filter

(Figure 1) is used to remove the power line frequency and its harmonics. The remaining voltage is applied to an RMS digital voltmeter. The frequencies that are measured are determined by the filter and the characteristic of the meter. The FLUKE 79 III meter responds to frequencies above 10,000 Hz. The voltage amplitude measured will be that present on wires and electrical equipment in that home, office, school or factory.[2] The amount capacitively coupled to a human will depend on many variables, but a larger voltage at the outlet will result in larger currents in the humans. The high frequency voltage originates in modern electrical equipment, particularly high efficiency electrical equipment. The level of this high frequency voltage will vary with what electrical equipment is on at that location and with the time of day, due to the varying load on the electrical utility system which also contributes to this pollution.

Experiments are being performed to improve the design of this instrument and the interpretation of the readings.

If the effect on humans is caused by the high frequency voltages and currents, it would be important that the experiments with 60 Hz voltages and currents use voltages and currents that are not contaminated with these high frequencies.

FILTER



INPUT from Ubiquitous AC Outlet

OUTPUT to FLUKE 79 III meter set to VOLTS AC

All capacitors are .01 microfarad

All resistors are 10 kilohm

Figure 1

Footnotes

[1] *NIEHS Report on Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields, Prepared in Response to the 1992 Energy Policy Act (PL 102-486, Section 2118),* National Institute of Environmental Health Sciences, National Institutes of Health Publication No. 99-4493.

[2] Exploratory measurements of this voltage varied from tens of millivolts to hundreds of millivolts. The voltage induced by a two milligauss 60 Hz magnetic field passing through a one square meter area is less than .1 millivolt.

Energy Basics: Power Surges
The Causes

Power surges occur when the flow of electricity is interrupted, then started again, or when something sends electricity flowing back into the system.

Surges can range from five or ten volts when you turn on your hair dryer to thousands of volts if lightning strikes a transformer.

Internal power surges

More than half of household power surges are internal. These happen dozens of times of day, usually when devices with motors start up or shut off, diverting electricity to and from other appliances.

Refrigerators and air conditioners are the biggest culprits, but smaller devices like hair dryers and power tools can also cause problems.

External power surges

An external power surge, stemming from outside your home, is most commonly caused by a tree limb touching a power line, lightning striking utility equipment or a small animal getting into a transformer.

Surges can also occur when the power comes back on after an outage, and can even come into your home through telephone and cable TV lines.

Energy Basics: Power Surges
The Consequences

Your home is filled with items susceptible to power surges. Anything containing a **microprocessor** is especially vulnerable - the tiny digital components are so sensitive that even a 10-volt fluctuation can disrupt proper functioning.

Microprocessors are found in **hundreds of consumer items**, including TVs, cordless phones, computers, microwaves, and even seemingly "low-tech" large appliances like dishwashers, washing machines and refrigerators.

Large power surges, as with a lightning strike, can cause **instantaneous damage**, "frying" circuits and melting plastic and metal parts. Fortunately, these types of power surges are rare.

Low-level power surges won't melt parts or blow fuses, but they can cause "**electronic rust**," gradually degrading internal circuitry until it ultimately fails.

Small surges won't leave any outward evidence, so you may not even be aware they're happening - even though they may occur **dozens or even hundreds of times each day**.

Did you know?

A power surge usually lasts less than 1/120th of a second.

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Energy Basics: Power Surges
Preventing Power Surges

The first line of defense against power surges is **prevention**. While most external surges can't be controlled, you can eliminate some common causes of internal surges.

Did you know?

Your home may experience dozens or even hundreds of low-level internal power surges every day.

Unplug devices you aren't using

The easiest way to avoid power surge problems is to unplug devices that aren't being used. Take a look around your home, and you'll likely find dozens of idle items plugged in.

There's no need to leave toasters, power tools or other small appliances plugged in; if you rarely use the programming features on your microwave or VCR, unplug those as well.

Inadequate wiring

If you have an older home, inadequate wiring could be the cause. Electrical systems in homes built before the 1980s weren't designed to handle large-capacity refrigerators, entertainment systems and computer equipment.

Some visible signs of inadequate wiring are frequent blown fuses or tripped circuit breakers, or lights that flicker or dim when the refrigerator or another large appliance kicks on.

Don't ignore these symptoms - they're a signal that something is wrong, and the problem may become a fire hazard.

Overloaded circuits

If your home is newer, you may have a problem with an overloaded circuit. Look for two (or more) large appliances drawing power from the same circuit, especially in the kitchen.

Another troublespot might be a circuit with many smaller devices, such as a family room filled with computer and entertainment equipment.

Ask your electrician to establish dedicated circuits for each large appliance, and to divide rooms with multiple devices into separate circuits.

Energy Basics: Power Surges

Choosing a Surge Protector

For the items you can't leave unplugged, invest in high-quality surge protectors. They work by monitoring the flow of electricity and diverting excess voltage either back into the system or to the ground.

There are two types of surge protectors - to fully protect your electronics, using both types is a must.

Point-of-use surge protectors

A "point-of-use" surge protector guards individual devices from lower-level internal fluctuations.

You may have equipment plugged into a multi-socket power strip, but it's important to realize that many of these devices function simply as extension cords, providing little or no protection against power surges.

The adage "you get what you pay for" very much applies to surge protectors, with prices ranging from $5 to more than $150.

Did you know?

Many multi-socket "power strips" offer no protection against power surges.

Here's what to look for:

- **Enough connections** to protect all components of a system.
- An **on/off switch** allowing you to shut off power to every component.
- **UL-1449 rating** to ensure adequate testing by Underwriters Laboratories. Look for a specific UL rating, not just a label that says "UL Listed."
- An **indicator light** or **audible alarm** so you know a high-level surge has occurred.
- A **clamping voltage** of 330. This is the level at which the device begins to block the surge - the lower the clamping voltage, the better.
- The **total energy dissipation** - the higher the better.
- A **joule rating** of at least 400 is good; 600 is better. This is a measure of the ability to absorb surges.
- A **response time** of 10 nanoseconds or less.
- Protection between all **three wire combinations**: L-G, N-G, L-N.
- A **warranty** against damage to any connected equipment. Keep in mind that no surge protector will be fully warranted against lightning strikes.
- **Filters** for line noise, also known as electromagnetic interference.

Whole-house surge protectors

To protect against large external power surges, a whole-house protector is key. These devices cost around $150 to $300, and are installed on your meter or service panel by a licensed electrician.

Energy Basics: Power Surges
Using a Surge Protector

While most large appliances can withstand low-level power surges, **any programmable appliance** should be connected to a surge protector, including:

- Televisions
- VCRs and DVD players
- Video game systems
- Audio equipment
- All computer and home office equipment
- Cable and satellite TV boxes
- Cordless telephones, caller-ID devices and answering machines
- Home security systems
- Microwave ovens

Also remember that power surges can come into your home through other utility lines as well as electrical, so be sure to connect all incoming cable and satellite TV lines, and all telephone lines, including fax and modem.

Every component must be connected

If you have a computer or entertainment system, every component must be connected through a surge protector - one unprotected device can transmit a surge to every other piece of equipment.

For example, if you connect every piece of computer equipment through a protector except the modem line, surge can travel through the modem and spread to the other devices.

One-time only protection against large surges

Also keep in mind that both whole-house and strip protectors offer one-time only protection against large power surges - and no product can protect 100 percent against a catastrophic surge like a lightning strike. Check the indiçator lights on your surge protectors often, especially after storms. If a high-level surge has occurred, you'll need to replace the protectors - but your equipment will be safe.

Did you know?

One unprotected device can transmit a power surge to every other component in a system.

Energy Basics: Power Surges
Power Blinks

Have you ever come home to find your digital clocks flashing "12:00"? It's caused by a **power blink** - a brief interruption that's designed to prevent a longer power outage.

Blinks occur when an obstruction, like a tree limb, comes into contact with a power line or transformer. To minimize the possibility of damage to the utility system or your home, a circuit breaker interrupts the flow of electricity for a fraction of a second.

If the limb remains on the line, the breaker opens and tries to reclose again. If the obstruction is still on the line after the third try, the breaker opens and does not reclose automatically.

At this point, a utility worker must be dispatched to remove the obstruction and manually reset the breaker.

Power blinks rarely cause damage to equipment. Older digital clocks and other devices are the most vulnerable to blinks; newer models are designed to ride out these small voltage fluctuations.

If you're experiencing frequent power blinks, call your electric company.

Did you know?

Power blinks have always been a part of electric service - they just weren't as noticeable until sensitive electronic equipment began filling our homes.

Solutions of EMI Problems From Operation of Variable-Frequency Drives

[Power Quality In Your Home | Power Quality Check List | Understanding Electric Power Characteristics | Notes on Surge Suppressors | Uninterruptible Power Supply | Solution of EMI Problems | Application of Line or DC Link Reactors | Voltage Tolerance Boundary | Power System Harmonics | Telecommunications Interference]

Abrupt voltage transitions on the output terminals of a variable-frequency drive (VFD) are an inherent source of radiated and conducted Electromagnetic Interference (EMI). These voltage transition times are essentially determined by the rise and fall time of the semiconductor devices used in the inverter section of VFDs.

The present tendency among drive manufacturers is to use Insulated-Gate-Bipolar-Transistor (IGBTs) devices which have a much lower power loss and higher switching speed than their predecessors Bipolar Junction Transistors (BJTs). However, these improvements result in voltage transition times that can now be as fast as 100 ns and this high dv/dt produces higher magnitude of common-mode (CM) noise currents in the stray line-to-ground capacitance of motor and cables. These CM noise currents can cause electromagnetic interference and affect control signals, encoder feedback, communication links for programmable logic controllers, including RS-232, RS 484, Remote I/O, and different types of sensors including, ultrasonic sensors, bar code/vision systems, weight and temperature sensors. Conducted ground current also leads to radiated emissions, with the drive cables acting as antennas. AM radio reception, radio-controlled operator devices, and television are the most susceptible equipment to this radiated interference from VFDs. The purpose of this power note is to explain the issues related to EMI problems associated with VFD operation, and to provide recommended guidelines for end-users toward mitigating EMI problems related to VFD operation.

Problem Description

EMI-related problems involve a source of noise, coupling of this noise by conduction or radiation, and circuits/equipment that are susceptible to this noise. The source of noise from VFD operation is the high dv/dt of pulse-width modulated (PWM) output voltage waveforms. As can be seen from Figure 1, the stray capacitance to ground of cables and motors results in high frequency ground currents, the magnitude of which is determined by the equation $I = C\, dv/dt$.

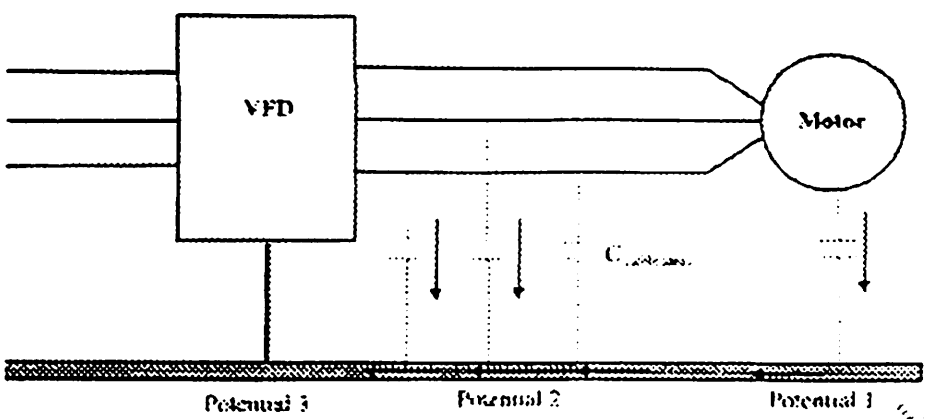


Figure 1 -- Capacitive Coupled Noise Current from Unshielded Phase Conductor of VFD

The high ground impedance at high frequency results in instantaneous voltage differences between two points reputed to be "ground potential." This voltage appears as a common-mode noise voltage that can interfere with control signals and other communication devices. CM noise may also be capacitively coupled onto control signal cables that are in close proximity of unshielded VFD power leads. Conducted ground currents also lead to radiated interference, with the unshielded phase conductor, the stray capacitance, and the ground return path acting as a loop antenna. With the increasing use of VFDs in commercial and residential applications, the possibility of radio interference from VFDs is an issue of concern for end-users. Sometimes this radio interference can affect other customers in the neighborhood of the VFD application.

The rise time of the VFD output waveform and the switching frequency of the inverter determine the frequency of the radiated and conducted noise. The switching frequency, which is typically in the range of 1 kHz to 16 kHz, determines the low-frequency conducted noise spectrum. The rise time of modern IGBT inverters can be in the range of 50 ns to 500 ns. This results in a noise frequency $fn = 0.318/Trise$, respectively 6 MHz to 600 kHz.

Preventive Measures to Minimize EMI Problems

EMI problems can be minimized to a great degree by adopting preventive measures during the installation phase of VFDs. The most successful preventive measure is to use a shielded power cable to connect the VFD to the motor. This forces the noise current to flow through the shield back to the inverter, before it gets out into the system grid and takes multiple high frequency paths which are difficult to track down in an installation.

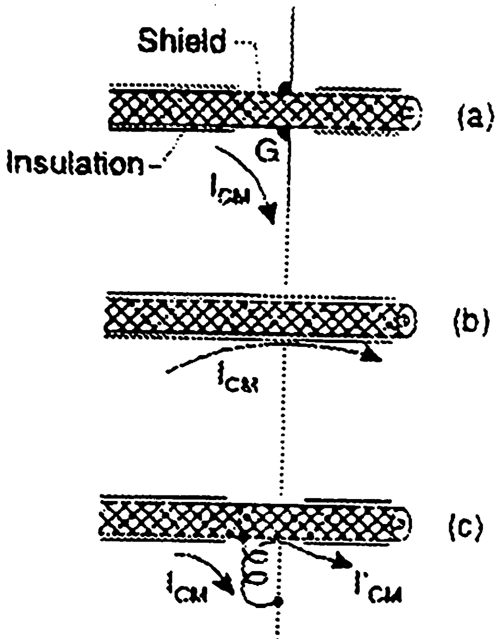


Figure 2 -- Cable shield bonding.
Incorrect (a) and (b)
Correct (c)

The use of shielded power cables also reduces the area of the loop antenna that is responsible for radiated interference. The shield should be connected to ground at both ends. It is important to ensure good electrical contact from the installation plate through the installation screws to the metal cabinet of the VFD. Cable clamps should be used instead of twisted shield ends (pigtails, see Figure 2), since this ruins the shielding effect at high frequencies.

If a shielded cable is not used, avoid random lay of unshielded cables in cable troughs. Using 3-wire plus ground conductor ("green wire") in a conduit ensures some degree of noise abatement as the conduit and the green wire carry most of the return current. However, accidental contact with grid ground structure due to strap supports, etc. is still a possibility. In contrast, with a shielded cable, this situation can be avoided by using a PVC outer coating.

In addition to the use of shielded power cable, the following noise reduction practices are usually employed for control signal wiring practice:

- Twist the leads to provide a balanced capacitive coupling.
- Use shielded cable to return the noise current flowing in the shield back to the source, instead of through the signal leads.
- Maintain at least 8-inch separation between control and power wires in open air, conduit or cable trays.
- Use a common-mode choke wound with multiple turns of both signal and shield.
- Use optical isolation modules for control signal communications.

EMI Mitigating Devices

Common mode chokes (CMCs) and EMI filters are the two principal mitigating devices commonly used in VFD application for reducing EMI interference. A common-mode choke is an inductor with the three phase conductors wound in the same direction through a common magnetic core, typically torroidal in shape (Figure 3). The CMC, when used on VFD output leads provides a high impedance to any line-to-ground capacitive noise current generated during the fast transition time of the output voltage waveform. The CMC does not affect the line-to-line power circuit and takes up less physical space, in contrast with an output line reactor. The phase-conductor inductance of a line reactor reduces motor phase voltage, lowering the available motor output torque.

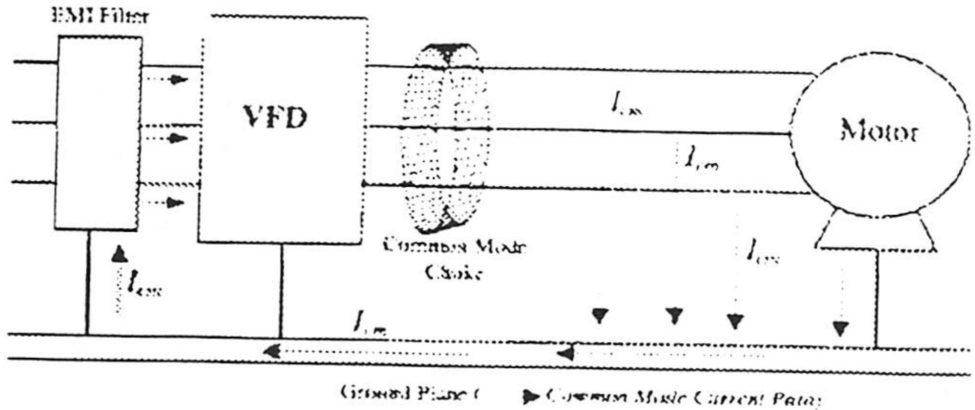


Figure 3 -- Mitigating common mode effects by impeding flow of common mode currents with a Common Mode Choke or by providing low-impedence path with an EMI filter.

EMI filters for VFD applications are typically structured as low-pass filters with series inductance and bypass capacitors connected in line-to-ground mode. These filters are usually installed on the input leads of the VFD. The line-to-ground by-pass capacitors in the filter provide a low impedance path for the CM noise currents (Icm in Figure 3) to flow back to the VFD input out of the ground. The CM and phase inductors or the EMI filter provide high impedance to the high-frequency noise current. Drive-based equipment that must meet the European CE conformity must use an EMI/RFI filter connected to the drive input.

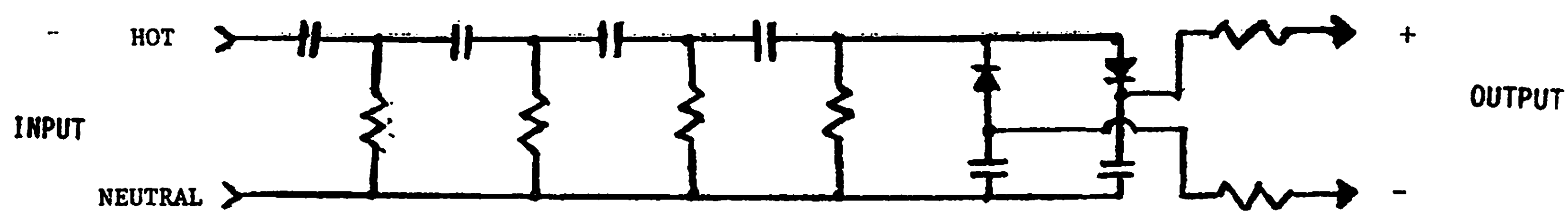
European Union Basic EMC Standard Applicable for VFDs For new installations, end-users can require the VFD vendor to meet applicable European Union (EU) standards for drives in order to avoid potential EMI problems. These standards set the allowable emission limits for conducted and radiated disturbances. Table 1 presents a summary of these emission limits. Standard EN50081-1, Electromagnetic Compatibility Generic Emission Standard - Part 1: Residential, Commercial and Light Industrial. Standard EN50081-2, Electromagnetic Compatibility Generic Emission Standard - Part 2: Industry.

Frequency Range	Conducted Emissions 50 kHz-30 MHz	
	Residential, Commercial, and Light Industry EN 50081-1 and CISPR 22, Class B	Industry EN 50081-2 and CISPR 11, Class A
150 - 500 kHz	56 - 46 dBµV (Average) 66 - 56 dBµV (Quasi-Peak)	66 dBµV (Average) 79 dBµV (Quasi-Peak)
0.5 - 5 MHz	46 dBµV (Average) 56 dBµV (Quasi-Peak)	60 dBµV (Average) 73 dBµV (Quasi-Peak)
5 MHz - 30 MHz	50 dBµV (Average) 60 dBµV (Quasi-Peak)	60 dBµV (Average) 73 dBµV (Quasi-Peak)

Frequency Range	Radiated Emissions 50 kHz-30 MHz	
	Residential, Commercial, and Light Industry EN 50081-1 and CISPR 22, Class B	Industry EN 50081-2 and CISPR 11, Class A
30 - 230 MHz	30 dBµV/m @ 10m	30 dBµV/m @ 10m
230 MHz - 1 GHz	37 dBµV/m @ 10m	37 dBµV/m @ 10m

APPENDIX E

COMBINED FILTER AND PEAK DETECTOR



INPUT from POLARIZED UBIQUITOUS AC OUTLET

OUTPUT to DIGITAL DC VOLTMETER with 10 MEGOHM INPUT RESISTANCE

THE FOUR RESISTORS IN THE FILTER ARE 10 kilohms

ALL THE CAPACITORS ARE .01 microfarads

THE DIODES IN THE PEAK DETECTOR ARE 1N4148 diodes

THE PROTECTION RESISTORS IN THE OUTPUTS ARE 270 kilohms