LINCOLN ELECTRIC | Cutting Systems

Concepts of Signal Noise Reduction

Shielding and Grounding

TORCHMATE
A Lincoln Electric Company

August 12, 2013

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Technical Support

When upgrading your CNC Cutting System, if a question or concern arises, or a part is missing, please contact Torchmate Technical Support.

Technical Support will also help you with operating the CNC system, and troubleshooting problems.

Technical Support is available Monday through Friday from 6 AM to 4 PM (06:00 to 16:00) Pacific Time Zone.

Call, Fax, or Email

TORCHMATE
A Lincoln Electric Company

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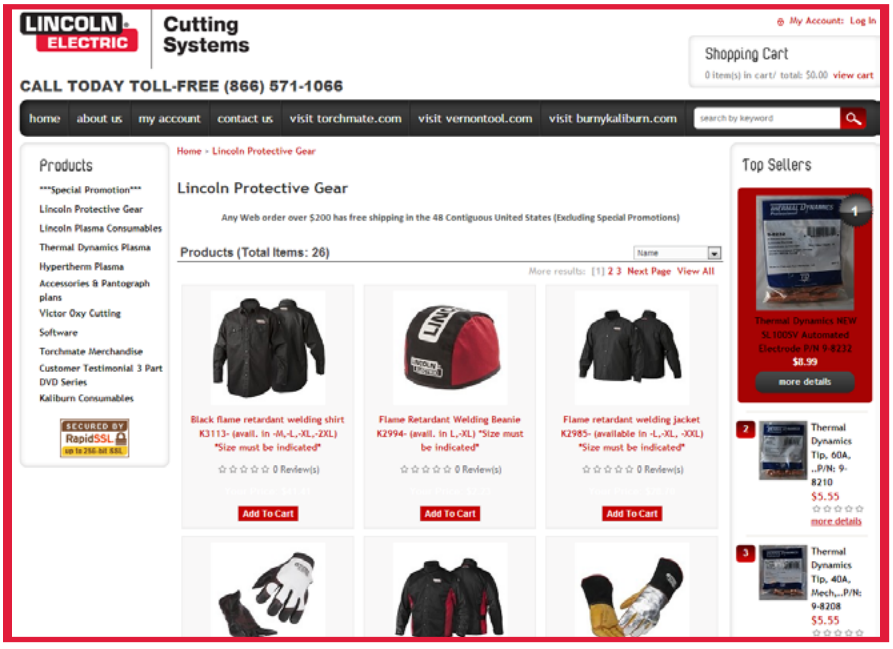
Email: support@torchmate.com



Call us for Consumables, or visit our web store

www.TorchmateStore.com

Safety First

Lincoln Electric Cutting Systems equipment is designed and built with everyone's safety in mind. However, your overall safety can be increased by proper installation—and by thoughtful operation on your part.

WARNING

DO NOT INSTALL, OPERATE, OR REPAIR THIS EQUIPMENT WITHOUT READING THE SAFETY WARNINGS CONTAINED THROUGHOUT THIS MANUAL.

Think before you act—and be careful.

PROTECT YOURSELF AND OTHERS FROM POSSIBLE SERIOUS INJURY OR DEATH.

KEEP CHILDREN AWAY. ALLOW NOBODY YOUNGER THAN 14 NEAR THIS EQUIPMENT.

IF YOU WEAR A PACEMAKER, CONSULT WITH YOUR DOCTOR BEFORE OPERATING.

Read and understand the following safety highlights. For additional safety information it is strongly recommended that you purchase a copy of "Safety in Welding & Cutting - ANSI Standard Z49.1" from the American Welding Society, P.O. Box 351040, Miami, Florida 33135 or CSA Standard W117.2.

BE SURE THAT ALL INSTALLATION, OPERATION, MAINTENANCE, RELOCATION, AND REPAIR PROCEDURES ARE PERFORMED ONLY BY QUALIFIED INDIVIDUALS.

Electric Shock

1. ELECTRIC SHOCK can kill.

1.1 The electrode and work (or ground) circuits are electrically "hot" when the power source is on. Do not touch these "hot" parts with your bare skin or wet clothing. Wear dry, hole-free gloves to insulate hands.

1.2 Disconnect the power source before performing any service or repairs. When the power source is operating, voltages in excess of 250 volts are produced. This creates the potential for serious electrical shock - possibly even fatal.

1.3 Insulate yourself from work and ground using dry insulation. Wear dry gloves and clothing. Take extra care when the work place is moist or damp.

1.4 Always be sure the work cable makes a good electrical connection with the metal being cut or gouged. The connection should be as close as possible to the area being cut or gouged.

1.5 Ground the work or metal to be cut or gouged to a good electrical (earth) ground.

1.6 Maintain the plasma torch, cable and work clamp in good, safe operating condition. Repair or replace all worn or damaged parts. Replace damaged insulation.

1.7 Never dip the torch in water for cooling or plasma cut or gouge in or under water.

1.8 When working above floor level, protect yourself from a fall should you get a shock.

1.9 Operate the pilot arc with caution. The pilot arc is capable of burning the operator, others or even piercing safety clothing.

1.10 Also see Items 4.3 and 6.

2. ARC RAYS can burn.

Arc Rays

2.1 Plasma Arc Rays can injure your eyes and burn your skin. The plasma arc process produces very bright ultraviolet and infrared rays. These will damage your eyes and burn your skin if you are not properly protected.

2.2 Use safety glasses and a shield with the proper filter and cover plates to protect your eyes from sparks and the rays of the arc when performing or observing plasma arc cutting or gouging. Glasses, head-shield, and filter lens should conform to ANSI Z87. I standards.

Arc Current	Minimum Shade No.	Suggested Shade No.
Less than 20A	4	4
20A-40A	5	5
40A-60A	6	6
60A-300A	8	9
300A-400A	9	12
400A-800A	10	14

2.3 Use suitable clothing including gloves made from durable flame-resistant material to protect your skin and that of your helpers from the arc rays.

2.4 Protect other nearby personnel with suitable non-flammable screening and/ or warn them not to watch the arc nor expose themselves to the arc rays or to hot spatter or metal.

3. FUMES AND GASES can be dangerous.

Fumes, Gases and Dust

3.1 Plasma cutting or gouging may produce fumes and gases hazardous to health. Avoid breathing these fumes and gases. When cutting or gouging, keep your head out of the fumes. Use enough ventilation and/or exhaust at the arc to keep fumes and gases away from the breathing zone.

3.2 Use an air-supplied respirator if ventilation is not adequate to remove all fumes and gases.

3.3 When plasma cutting or gouging on lead or cadmium plated steel and other metals or coatings which produce highly toxic fumes, keep exposure as low as possible and within applicable OSHA PEL and ACGIH TLV limits using local exhaust or mechanical ventilation. In confined spaces or in some circumstances, outdoors, a respirator may be required.

3.4 Additional precautions are also required when cutting (zinc) galvanized steel or materials containing or coated with any of the following:

Antimony	Beryllium	Cobalt	Manganese	Selenium
Arsenic	Cadmium	Copper	Mercury	Silver
Barium	Chromium	Lead	Nickel	Vanadium

3.5 The operation of plasma cutting or gouging fume control equipment is affected by various factors including proper use and positioning of the equipment, maintenance of the equipment, and the specific procedure and application involved. Worker exposure levels should be checked upon installation and periodically thereafter to be certain levels are within applicable OSHA PEL and ACGIH TLV limits. For information on how to test for fumes and gases in your work place, refer to publications section of this manual.

Safety First (continued)

3.6 Do not use plasma cutting or gouging equipment in locations near chlorinated hydrocarbon vapors coming from degreasing, cleaning or spraying operations. The heat and rays of the arc can react with solvent vapors to form phosgene, a highly toxic gas, and other irritating products. Remove all sources of these vapors.

3.7 Gases used for plasma cutting and gouging can displace air and cause injury or death. Always use enough ventilation, especially in confined areas, to insure breathing air is safe.

3.8 Read and understand the manufacturer's instructions for this equipment and follow your employer's safety practices.

3.9 This product, when used for cutting, produces fumes or gases which contain chemicals known to the State of California to cause birth defects

3.10 Some dust created by routing, sawing, grinding, drilling, and other construction activities contains chemicals known to cause cancer, birth defects or other reproductive harm. Avoid prolonged contact with this dust. Wear protective clothing and wash exposed areas with soap and water. Allowing dust to get into your mouth, eyes, or lay on the skin may promote absorption of harmful chemicals.

Some examples of these chemicals are:

- Lead from lead-based paint.
- Crystalline silica from bricks and cement and other masonry products.
- Arsenic and chromium from chemically-treated lumber (CCA).

3.11 Your risk from these exposures varies, depending on how often you do this type of work. To reduce your exposure to these chemicals: work in a well ventilated area, and work with approved safety equipment, such as those dust masks that are specially designed to filter out microscopic particles.

Fire or Explosion

4. Cutting flame and sparks can cause FIRE OR EXPLOSION.

4.1 Fire and explosion can be caused by hot slag, sparks, oxygen fueled cutting flame, or the plasma arc.

4.2 Have a fire extinguisher readily available. Provide a fire watch when working in an area where fire hazards may exist.

4.3 When not cutting or gouging, make certain no part of the electrode circuit is touching the work or ground. Accidental contact can cause overheating and create a fire hazard.

4.4 Be sure there are no combustible or flammable materials in the workplace. Any material that cannot be removed must be protected.

4.4.1 Sparks and hot materials from cutting or gouging can easily go through small cracks and openings to adjacent areas.

4.4.2 Avoid cutting or gouging near hydraulic lines.

4.4.3 Do not cut or gouge tanks, drums or containers until the proper steps have been taken to insure that such procedures will not cause flammable or toxic vapors from substances inside. They can cause an explosion even though they have been "cleaned." For information purchase "Recommended Safe Practices for the Preparation for Welding and Cutting of Containers and Piping That Have Held Hazardous Substances", AWS F4.1 from the American Welding Society (see address above).

4.4.4 Vent hollow castings or containers before heating, cutting or gouging. They may explode.

4.5 Do not add fuel to engine driven equipment near an area where plasma cutting or gouging is being done.

4.6 Connect the work cable to the work as close to the cutting or gouging area as practical. Work cables connected to the building framework or other locations away from the cutting or gouging area increase the possibility of the current passing through lifting chains, crane cables or other alternate circuits. This can create fire hazards or overheat lifting chains or cables until they fail.

4.7 Hydrogen gas may be formed and trapped under aluminum work pieces when they are cut underwater or while using a water table. DO NOT cut aluminum alloys underwater or on a water table unless the hydrogen gas can be eliminated or dissipated. Trapped hydrogen gas that is ignited will cause an explosion. For further safety information related to cutting aluminum on water tables, and in particular dual-chamber tables, please consult the Owner's Manual and appropriate Safety Notices.

4.8 Read and follow NFPA 51B " Standard for Prevention During Welding, Cutting and Other Hot Work", available from NFPA, 1 Batterymarch Park,PO box 9101, Quincy, Ma 022690-9101.

5. CYLINDER may EXPLODE if damaged.

Cylinder Explosion

5.1 Use only compressed gas cylinders containing the correct gas for the process used and properly operating regulators designed for the gas and pressure used. All hoses, fittings, etc., should be suitable for the application and maintained in good condition.

5.2 Always keep cylinders in an upright position securely chained to an undercarriage or fixed support.

5.3 Cylinders should be located: • Away from areas where they may be struck or subjected to physical damage. • A safe distance from plasma cutting or gouging, arc welding operations and any other source of heat, sparks, or flame.

5.4 Never allow any part of the electrode, torch or any other electrically "hot" parts to touch a cylinder.

5.5 Keep your head and face away from the cylinder valve outlet when opening the cylinder valve.

5.6 Valve protection caps should always be in place and hand tight except when the cylinder is in use or connected for use.

5.7 Read and follow the instructions on compressed gas cylinders, associated equipment, and CGA publication P-l, "Precautions for Safe Handling of Compressed Gases in Cylinders,"available from the Compressed Gas Association 1235 Jefferson Davis Highway, Arlington, VA 22202.

6. FOR ELECTRICALLY powered equipment.

Electrical Power

6.1 Turn off input power using the disconnect switch at the fuse box before working on the equipment.

6.2 Install equipment in accordance with the U.S. National Electrical Code, all local codes and the manufacturer's recommendations.

6.3 Ground the equipment in accordance with the U.S. National Electrical Code and the manufacturer's recommendations.

7. PLASMA ARC can injure.

Plasma Arc

7.1 Keep your body away from nozzle and plasma arc.

7.2 Operate the pilot arc with caution. The pilot arc is capable of burning the operator, others or even piercing safety clothing.

Safety First (continued)

Electric and Magnetic Fields

8. ELECTRIC AND MAGNETIC FIELDS may be dangerous

8.1 Electric current flowing through any conductor causes localized Electric and Magnetic Fields (EMF). Cutting or gouging current creates EMF fields around torch cables and cutting machines.

8.2 EMF fields may interfere with some pacemakers, so operators having a pacemaker should consult their physician before cutting or gouging.

8.3 Exposure to EMF fields during cutting or gouging may have other health effects which are now not known.

8.4 All operators should use the following procedures in order to minimize exposure to EMF fields from the cutting or gouging circuit:

8.4.1 Route the torch and work cables together - Secure them with tape when possible.

8.4.2 Never coil the torch cable around your body.

8.4.3 Do not place your body between the torch and work cables. If the torch cable is on your right side, the work cable should also be on your right side.

8.4.4 Connect the work cable to the workpiece as close as possible to the area being cut or gouged.

8.4.5 Do not work next to cutting power source.

Automatic Operation

9. AUTOMATIC OPERATION

9.1 Any CNC machine may begin to operate automatically without warning. Only a trained individual familiar with the software, machine, and computer system should operate this equipment.

9.2 Keep the immediate area around the CNC machine clear of materials that may cause interference. Keep area clear of bystanders.

9.3 All untrained persons should not work on or near a CNC machine. Do not leave the CNC machine unattended while power is on to any electronics.

Noise

10. NOISE

10.1 Noise can cause permanent hearing loss. CNC operation, plasma arc cutting, plate marking, routing, and drilling can cause noise levels that exceed safe limits. You must protect your ears from loud noise to prevent permanent loss of hearing.

10.1.1 To protect your hearing from loud noise, wear protective ear plugs and/or ear muffs. Protect others in the workplace.

10.1.2 Noise levels should be measured to be sure the decibels (sound) do not exceed safe levels.

10.2 For information on how to test for noise refer to the publications section of this manual.

Heavy Parts

11. HEAVY PARTS

11.1 Parts of CNC machines are heavy. Also, material you are cutting may be heavy. Use caution when lifting or moving them. To avoid injury, get someone to help you, or use a mechanical lifter. When using a mechanical lifter, follow all the manufacturer's safety guidelines.

11.2 Review the Occupational Safety & Health Administration (OSHA) technical manual Sect. 7, Ch 1.5. See the publications section that follows.

12. FLYING DEBRIS

12.1 Metal cutting and marking operations create waste that can fragment and fly. Make sure you have proper eye protection and that everyone close to the CNC operations has proper eye protection, too.

12.2 Review the ANSI Z87.1 requirements. See the publications section for additional information.

Flying Debris

13. PINCH AND CRUSH POINTS

13.1 Pinch and crush points are those normally moving parts of machinery, like CNC machines, that can pinch, capture, crush, or sever parts of your body. Be aware of hazardous pinch and crush points.

13.2 Don't repair or adjust the machine with the controls on.

13.3 When the end of a CNC machine's travel creates a "hard stop," it creates a crush point. Keep fingers and hands away from this.

13.4 Do not stack or store any additional items in contact with the machine. These could create additional pinch or crush points, or could create a falling hazard.

13.5 Smaller limbs, hands, and fingers can fit into places that create additional pinch or crush points. Do not allow anyone younger than 14 years old to operate this equipment or reach into it when its power is connected.

Pinch & Crush Points

14. SHARP ROTARY TOOLS

14.1 Routing and drilling use high-speed rotating bits and cutters with sharp edges. Keep clear of bits when in use.

14.2 Turn the router, spindle, or drill off when changing bits. Be careful of the sharp edges.

Rotarv Tools

15. HOT MATERIAL

15.1 Plasma cutting uses an electric arc that can reach temperatures of 45,000°F (25,000°C). Oxygen-fuel cutting flames can be up to 6,330°F (3,500°C). Any parts and scrap will be very hot after cutting. Use extreme care.

15.2 Use tongs and wear protective gloves when handling recently cut material. Also, consider other devices for safe hot material handling.

15.3 It is safest to let material cool completely before handling.

Hot Material

16. MECHANICAL DRIVES

16.1 High-speed mechanical drives made of gears, belts, and or drive screws are used by CNC machines. Keep clear of them during operation.

16.2 Do not attempt to service, adjust, or otherwise touch these components while the machine is on.

16.3 Secure loose clothing and cables to prevent entanglement.

Mechanical Drives

17. AIR LINES UNDER PRESSURE

17.1 Some tools use compressed air or gases. Often flexible tubing (lines) bring the high-pressure air or gas to the machine. Inspect these lines periodically. Repair or replace damaged lines.

17.2 Hot sparks, flying debris, other objects, or vehicles can melt, burn, or puncture these lines. Check them for punctures, burns, or other damage or defects that could cause failure.

17.3 Route the air lines to keep them away from traffic and from underfoot.

Pressurized Air Lines

Safety First (continued)

PUBLICATIONS Refer to the following standards or their latest revisions for more information:

- OSHA, SAFETY AND HEALTH STANDARDS, 29CFR 1910, obtainable from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402
- ANSI Standard Z49.1, SAFETY IN WELDING AND CUTTING, obtainable from the American Welding Society, 550 N.W. LeJeune Rd, Miami, FL 33126
- NIOSH, SAFETY AND HEALTH IN ARC WELDING AND GAS WELDING AND CUTTING, obtainable from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402
- ANSI Standard Z87.1, SAFE PRACTICES FOR OCCUPATION AND EDUCATIONAL EYE AND FACE PROTECTION, obtainable from American National Standards Institute, 1430 Broadway, New York, NY 10018
- ANSI Standard Z49.2, FIRE PREVENTION IN THE USE OF CUTTING AND WELDING PROCESSES, obtainable from American National Standards Institute, 1430 Broadway, New York, NY 10018
- AWS Standard A6.0, WELDING AND CUTTING CONTAINERS WHICH HAVE HELD COMBUSTIBLES, obtainable from American Welding Society, 550 N.W. LeJeune Rd, Miami, FL 33126
- NFPA Standard 51, OXYGEN-FUEL GAS SYSTEMS FOR WELDING, CUTTING AND ALLIED PROCESSES, obtainable from the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269
- NFPA Standard 70, NATIONAL ELECTRICAL CODE, obtainable from the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269
- NFPA Standard 51B, CUTTING AND WELDING PROCESSES, obtainable from the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269
- CGA Pamphlet P-1, SAFE HANDLING OF COMPRESSED GASES IN CYLINDERS, obtainable from the Compressed Gas Association, 1235 Jefferson Davis Highway, Suite 501, Arlington, VA 22202
- CSA Standard W117.2, CODE FOR SAFETY IN WELDING AND CUTTING, obtainable from the Canadian Standards Association, Standards Sales, 178 Rexdale Boulevard, Rexdale, Ontario, Canada M9W 1R3
- NWSA booklet, WELDING SAFETY BIBLIOGRAPHY obtainable from the National Welding Supply Association, 1900 Arch Street, Philadelphia, PA 19103
- ANSI Standard Z88.2, PRACTICE FOR RESPIRATORY PROTECTION, obtainable from American National Standards Institute, 1430 Broadway, New York, NY 10018

Concepts of Signal Noise Reduction

Shielding and Grounding

Codes and qualified personnel

Regulations exist at the federal, state, and local levels and whether or not they are clear or confusing, you are expected to comply with them. This guide is meant to provide a focus for your considerations and discussions—but, it is not meant to be taken as directions or instructions on how to modify your electrical system or equipment. Any electrical work should be undertaken only by qualified personnel.

Safety

- The primary concern when working with electrically-connected devices must always be to ensure safety.

- ELECTRIC SHOCK can kill!

Local regulations

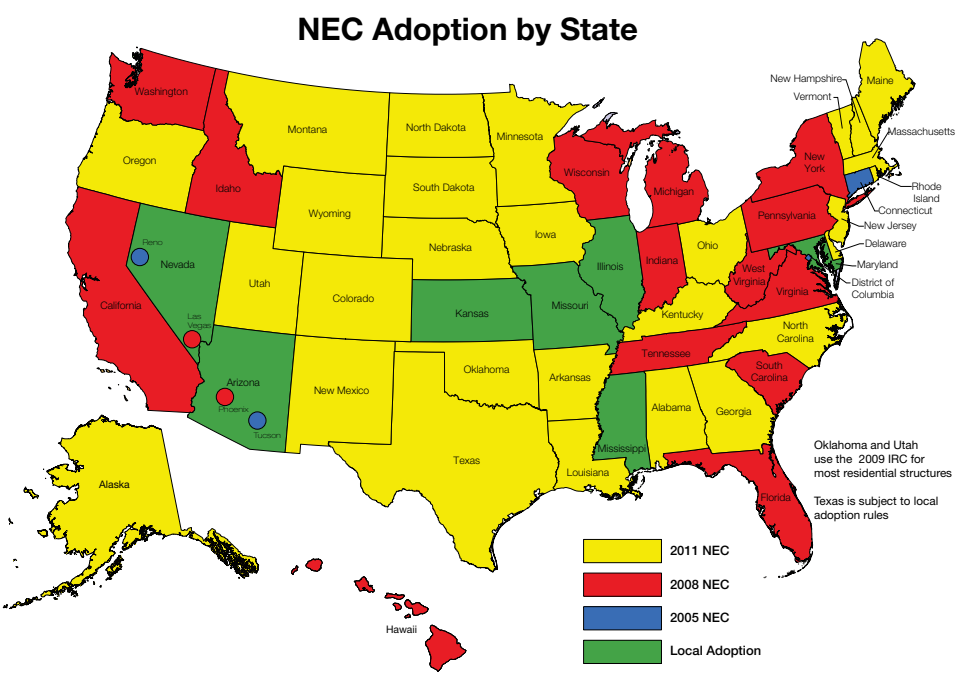
- You must comply with local regulations in your community whenever you obtain electrical utility service, employ electrical generating equipment, or make use of electrical appliances and equipment. As these regulations vary from location to location, you must become aware of and follow codes that apply in your area.

Qualified personnel

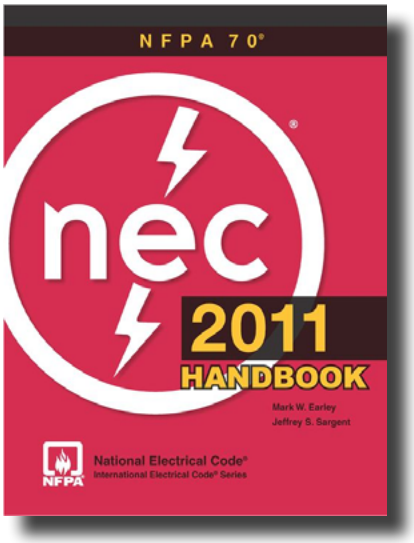
- In most places, a worker is considered qualified after obtaining the training or experience to be familiar with installing and using the equipment and with any associated hazards. In some locations, this may involve certified knowledge of electricity and electrical use, or membership at a particular level in a recognized labor union.
- Not all work involving the use of electricity or the installation or use of electrical equipment will require the skill of a qualified electrician, as distinguished from a qualified electrical worker, but in no case should unqualified personnel install, use, or alter electrical equipment.

NEC Codes and BICSI Codes

- The National Electrical Code (in various revisions) is the basis of most regulations for state and local jurisdictions. Check the rules of your local jurisdiction to determine the current requirements.
- The Telecommunications Distributions Methods Manual, published by the Building Industry Consulting Service International (BICSI) provides the most commonly used technical standard specifications for control of electro-magnetic interference (EMI). While not always included as a code requirement, this publication distills the best industry knowledge. Check your local requirements.



In the USA, different states and localities have adopted different versions of the NEC: Check with your local authorities



The TDMM is updated periodically and is now in its 12th Edition

The NEC codes are revised and updated every 3 years

EMI and noise overview

An “antenna” converts electric power into electromagnetic (radio) waves—or the other way around. Any wire carrying an electrical signal makes itself a broadcast antenna by sending out electromagnetic waves and any nearby wire becomes a receiving antenna when its location in the path of electromagnetic waves creates a signal in the wire. If this antenna effect transfers unwanted current and voltage to the receiving wire, it is called electromagnetic interference (EMI). EMI can result in difficult cutting operations and problems with cut quality.

EMI (aka RFI)

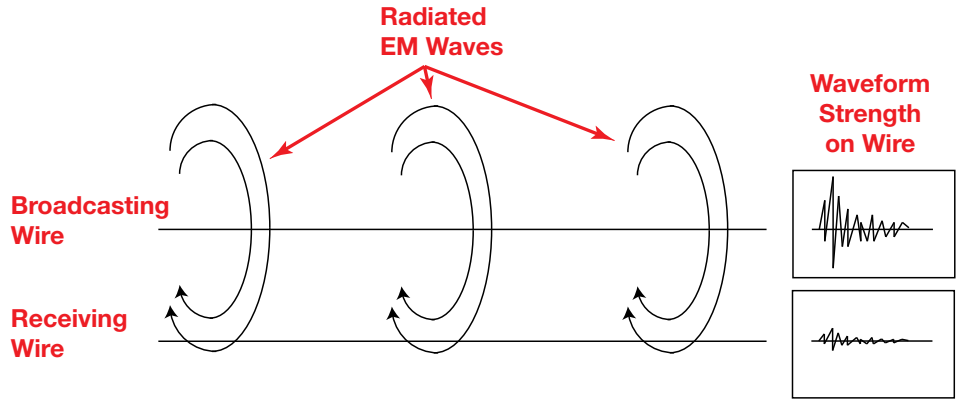
- Noise (random signals) and interference (from a different signal source) both function to decrease the quality of the signal you want.
- Noise and EMI (also known as radio frequency interference or RFI) is present in varying amounts in all circuits. EMI has other effects, such as interfering with radio reception.
- Good operation is achieved when the ratio of signal to noise-plus-interference (SNIR) is high. In this discussion, we will focus on increasing SNIR by reducing EMI, but some noise will be reduced as well.

Some factors that increase EMI

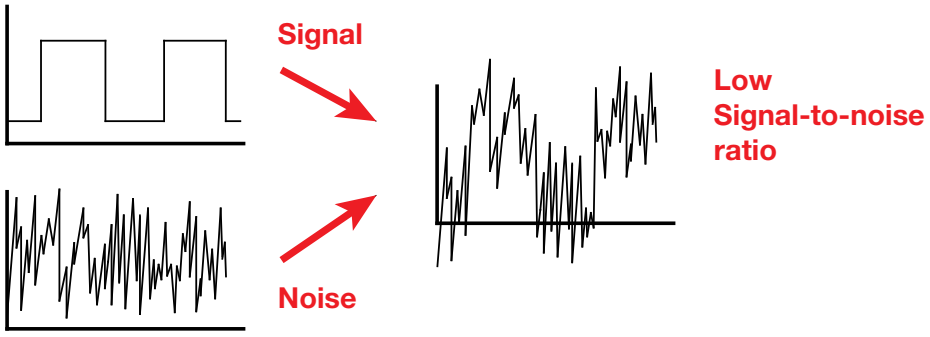
- In general, the following factors will increase EMI:
  - Longer conductors (sending and receiving)
  - Close proximity of sending and receiving conductors
  - Higher energy signals on the sending conductor
  - Higher frequency signals on the sending conductor
  - Capacitive or inductive coupling
  - Loose electrical connections

Factors that decrease EMI

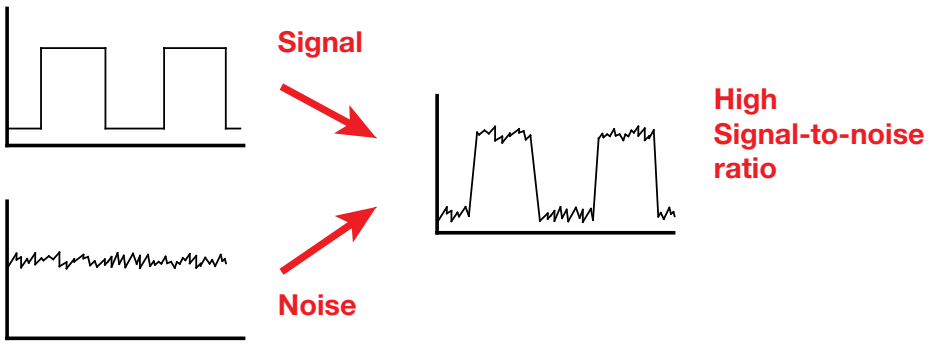
- In general, the following factors will decrease EMI:
  - Shorter conductors (sending and receiving)
  - Greater distance between sending and receiving conductors
  - Lower energy signals on the sending conductor
  - Lower frequency signals on the sending conductor
  - Shielding
  - Filtering
  - Tight electrical connections



Signal-carrying wires can function as “antennas”



Reduce noise to increase the signal-to-noise ratio



What produces EMI in your shop?

There are many potential EMI sources commonly found in shops, industrial buildings, and residential locations. The source can be anything that produces rapidly changing electrical currents. Radiated EMI travels through the air, while conducted EMI travels through wires.

Federal Regulations

- The Code of Federal Regulations, Title 47, Part 15, Subpart B governs **unintentional radiators**--devices, like computers, which are not designed to produce radio waves, yet may produce EMI.
- Other regulations, such as CISPR 22, may apply in other countries.

Typical sources of radiated EMI

- When EMI signals travel through the air from the transmitter to the receiver, the EMI is called “radiated.” Radiated sources in shops might include:
  - Plasma cutters, particularly during arc initiation
  - Arc Welders
  - Electric motors for shop tools, compressors, and venting fans
  - Transformers and fluorescent lighting ballasts
  - Resistance heaters
  - Computers and their peripherals including network equipment
  - Bluetooth and Wi-fi
  - Telephone equipment, cordless phones, and baby monitors
  - Appliances, such as microwave ovens or televisions

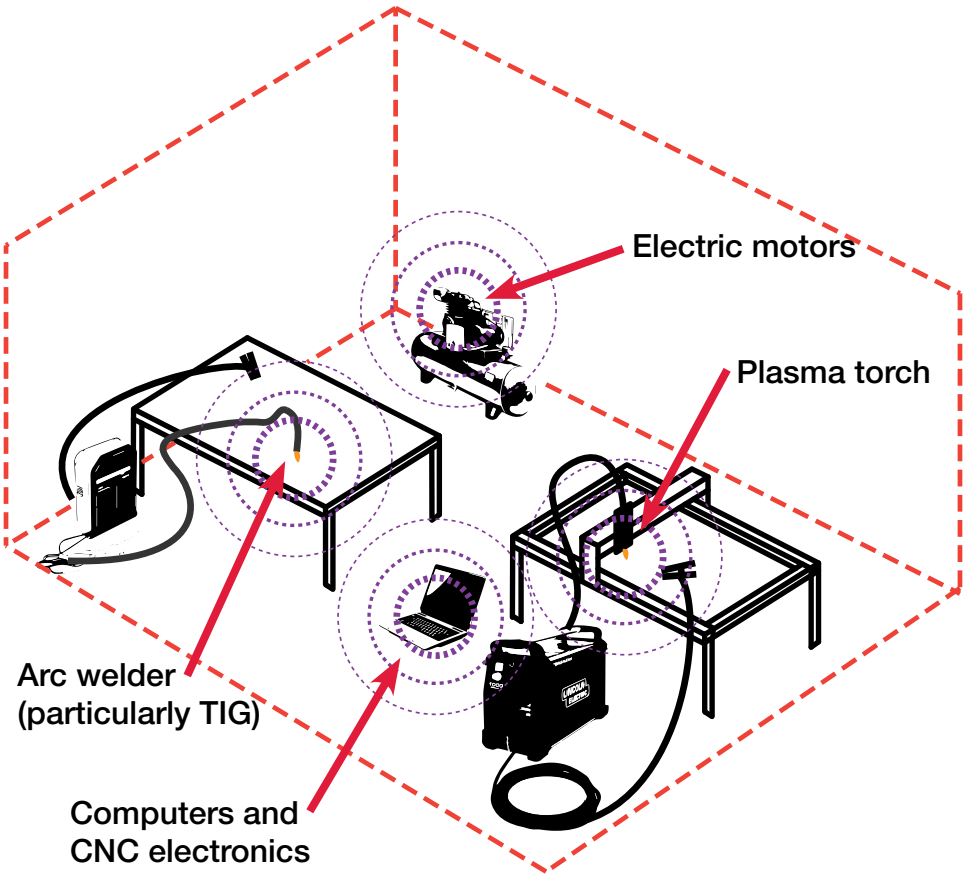
Conducted EMI

- The typical sources of radiated EMI can also produce interference in sensitive equipment when the EMI travels through the electrical power service connections, through the power distribution panel, or through the facility wiring. EMI can also travel through data cables, control signal cables, or power cables that run from the transmitter to the receiver.
- The same cable that conducts EMI to one device can also function as an antenna to radiate EMI to that device or to other sensitive devices. Combined radiation and conduction can create complex EMI interactions.

Other sources

- Other sources might include:
  - Vehicle ignition systems and aircraft, rail, or transit systems
  - Lightning strikes and smaller static discharges (carpet shocks)
  - Power line communication devices (such as X-10 systems)
  - Low power transmitters, such as hearing aids
  - Ham and CB radio
  - Large or powerful magnets or electromagnets

Some EMI sources in a typical shop



Where do EMI problems show up?

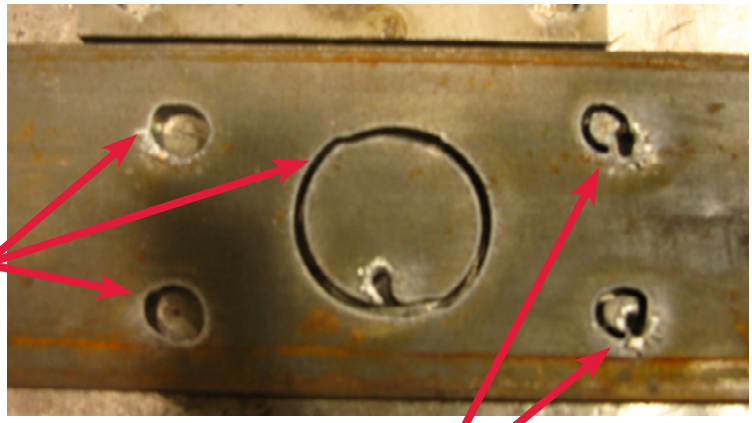
EMI in an industrial shop mostly causes problems with electronic data and equipment such as CAD / CAM computers and CNC controllers. Problems can include loss or corruption of data, restarting, or locking up. Other problems can happen with wireless devices, communication systems, and broadcast-based radio or television reception.

In electronic equipment

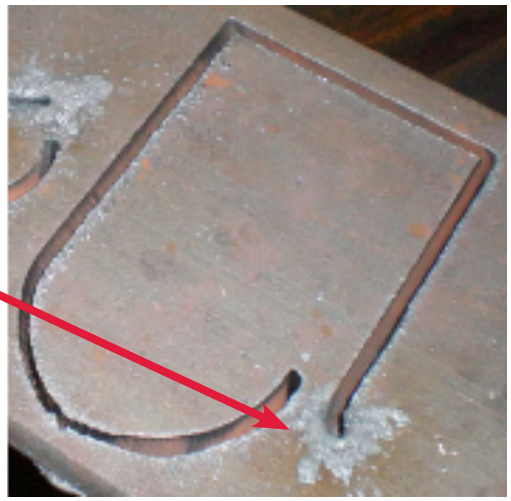
- When EMI enters an electronic device, it can induce voltages in the electronic components (e.g., memory, processors, interfaces, storage devices, etc.) that can alter either the data being processed, the program doing the processing, or both.
- In the worst cases (such as the facility being struck by lightning), the electronic components, can be completely destroyed by induced over-voltage. Discuss lightning protection with qualified electrical workers.

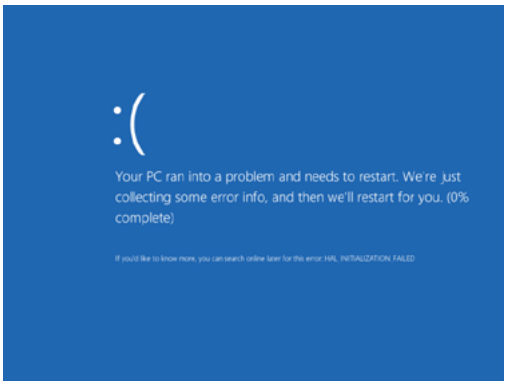
In poor quality cutting

- If your system is subjected to EMI that is corrupting data (or program instructions) in either the computer, the CNC interface, or any associated electronic equipment, you may see it as:
  - Mis-shaped parts
  - Incomplete cuts
  - Erratic cutter motion
  - Erratic Arc Voltage Height Control voltage readings and torch operation—particularly repeated rising and plunging of the torch (porpoising) during cuts.
  - Table motors out-of-synch or “fighting each other”
  - Computer or CNC interface freezing or resetting, particularly during torch arc startup
  - Erratic, unsteady voltage readings on the height control display



Examples of poor quality cutting, possibly be due to EMI





Computer freezeup or failure (e.g.: “blue screen of death”)

Steps to reduce EMI effects

Steps to reduce EMI can be categorized into several main groups, and the usual troubleshooting technique would apply for each group, including testing the lowest-cost, easiest-to-implement solutions first. This is not a detailed discussion, and you should consult with a qualified electrician before undertaking any modifications.

Distance

- If the EMI is coming from within an electronic device (as opposed to from its cables), then locating the source at a greater distance from other components will reduce EMI.
- If the EMI is being transmitted or received by the cables acting as antenna, then decreasing the cable length will reduce the EMI.

Cable routing

- Cables trade EMI (cross-talk) more easily when they touch or are close, cross each other at shallow angles, or are coiled together.
- Routing cables away from each other reduces EMI.

Shielding and grounding

- A firm, effective work clamp connection reduces arcing and EMI.
- Metal boxes surrounding circuit boards, and shielded cables prevent EMI from being transmitted or received when the box or shield is connected to signal-ground or earth-ground.
- A separate earth-ground may be helpful in dissipating EMI from shielded wires and equipment.

Filtering

- Ferrite donuts or chokes are passive filters that are often effective in reducing EMI from signal or power cables.
- If EMI is entering through the power lines, isolating equipment on its own electrical circuit and employing an inverter-based, battery-backed, un-interruptible power supply (UPS) can reduce EMI.

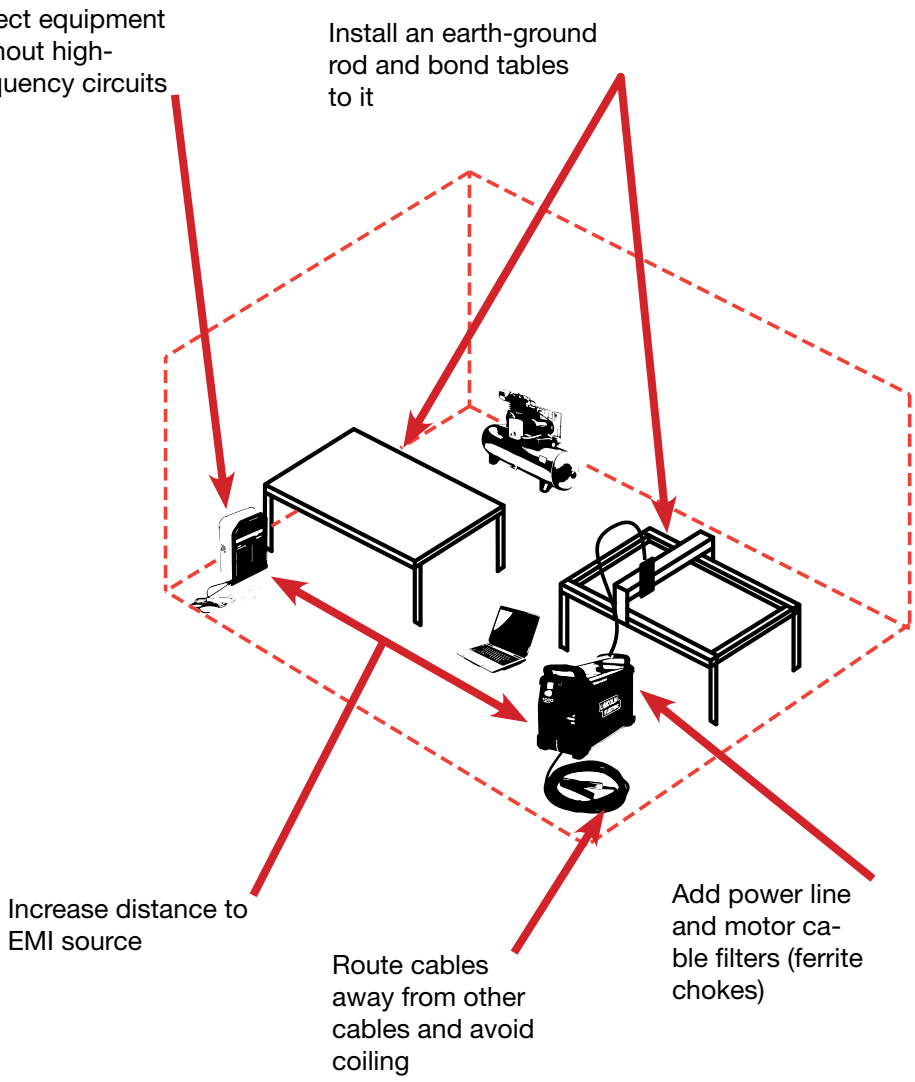
Frequency

- EMI problems increase when the frequency of signals increase, because high-frequency radiators produce EMI more effectively.
- Reducing operating frequencies (if possible, while maintaining economical performance) may reduce EMI.

Equipment selection

- When you select different equipment for your shop, you may want to consider the kinds which produce less EMI.
- As it gets older, some equipment will generate increased EMI. Other performance characteristics of older equipment may also decrease, but when replacing, keep the reduction of EMI in mind.

Various steps may be taken to reduce EMI



A voltage regulator placed between your power outlet and your electronics can filter EMI

This TrippLIte LC2400 Line Conditioner provides EMI filtration as well as voltage regulation

Other types of surge protectors are also available with EMI filtration

Equipment placement

EMI generated by welding and plasma cutting power supplies is generally more powerful when the sources are close to the effected equipment. Locate the sources as far away as practical from the computer and CNC controller (and other) electronics in your system.

Field strength

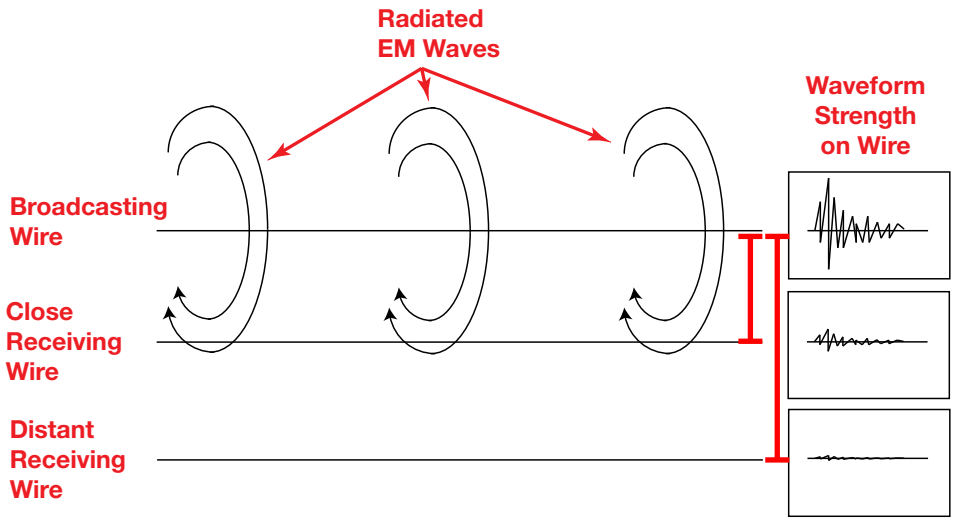
- Distance is important because EMI is radiated as electromagnetic fields and electromagnetic fields decrease with the mathematical "square" of the distance.
  - If you move a receiving antenna twice as far away from the source, the received signal decreases to ¼th and at 3 times as far away, the signal decreases to ⅑th of the original strength.
- Finding the best equipment placement can require some experimentation. Many factors go into reducing EMI by placing and aligning equipment so that EMI is decreased.

Distance and distance enhancement

- In general, the further your electronic equipment is from potential sources of directly broadcast EMI the better. Maintaining a distance effect could be enhanced by the following:
  - Introduce metallic objects between the transmitter and receiver if possible to absorb radiation. Bonding these objects to earth ground will dissipate the EMI before it reaches the electronics.
  - Enclose the electronics and computer in a metal cabinet. Bond the cabinet to earth ground.
  - If you use an electrically powered air compressor, keep it away from the electronics and computer, if possible. Otherwise, shield the motor with a metallic screen. Ground the shield to earth ground.
  - Other devices that have potential for producing RFI (such as additional shop computers, electrical motors and appliances, lighting systems, and transformers) should be located as far away as possible.

Orientation

- Sometimes EMI radiation will be reflected away, rather than being absorbed, if the angles or elevations of equipment are changed.
- Turn the electronics, computer, and welding / plasma equipment to varying angles or raise and lower their locations to re-orient the source and destination of EMI.



Increase the distance to the receiving wire to decrease EMI levels

Some antennas (like those for TV, radio, or astronomy) have been designed to swivel to INCREASE desired signal strengh.

Swivel (re-orient) your shop equipment to DECREASE undesired EMI signal strength

Cable routing

A cable that acts as either a transmitting antenna or a receiving antenna for high-frequency EMI signals will be less effective as an antenna when the distance separating it and other cables is *increased*, and it will similarly be less effective when the length of the cable is *decreased*.

Cable separation

- In the same way any added distance separating equipment reduces EMI, added distance between cables does, too. EMI radiates as fields which are weaker the further from the source. Moving a cable twice as far away creates a reduction of one-fourth the EMI.
- If possible, always keep a separation of two inches or more between motor cables / power cables, and any signal cables.

Short cables

- The shorter the cable, the less effective it is at transmitting or receiving EMI—within limits. For higher frequencies, even short cables can be effective antennas. For instance, with 100MHz EMI, a cable becomes effective as an antenna at about 6-in in length. Making cables shorter than this is generally not practical.

Cable crossing

- In almost every situation, some data or power cables (or both) must cross paths. EMI is worse when cables are parallel or cross at a shallow angle. The best method is to cross the cables perpendicular to each other. When they cross at 90-degrees, the level of “crosstalk” between the cables is reduced to its minimum.

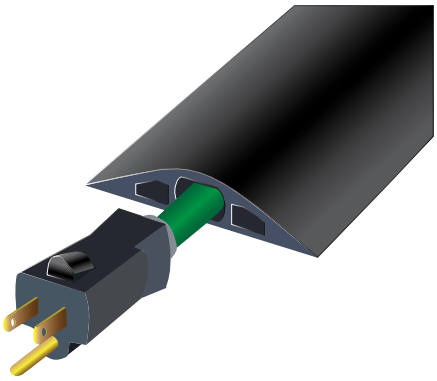
Cable coiling

- A coil of wire forms a kind of filter that can reduce signal strength and lower the signal-to-noise ratio. Because it creates a magnetic field (instead of an electric field) it is more difficult to control by shielding.

- Cables should be made no longer than the correct practical length. Slack lengths of cable can be a safety hazard and untidy, and can also help propagate EMI. Avoid coiling any excess lengths of plasma torch cables, arc welding cables, plasma or welder work cables, or power cables. Coils are more effective at radiating EMI due to the magnetic fields formed through the coils.
- Shielded cables, such as USB data cables, carry current in both directions with low voltages. This tends to cancel EMI signals. Coiling them produces less EMI than coiling unshielded cables.

Over and under coiling

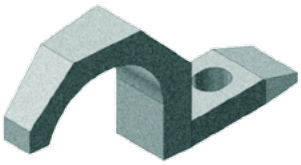
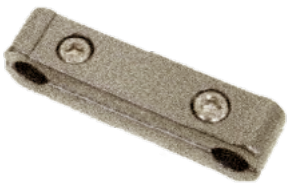
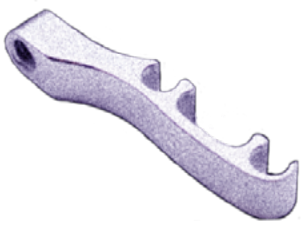
- If cables must be coiled, coil them “over and under” to cancel the EMI. Reverse the twist on successive coils, laying them on the same side. One coil twists over, the next twists under. Instructions for “over and under coiling” are available on the Internet.



Be safe and protect cables with molded rubber ducts

Avoid tangled cables

Keep cable routes tidy and well thought-out to reduce EMI

	
Cable Strap	Cable Loom
	
Cable Loom / Strap combo	Cable Raceway

Various products can be purchased (or fabricated) to create organized cable runs in the shop

Shielding and “grounding”

Shielding is a way to reduce the amount of EMI a cable will transmit or receive when it acts as an antenna. Shielding also can prevent unwanted radiation from entering or escaping from a device containing electronic circuits. Either way, the shield requires a “reference potential” (ground) connection to dissipate the EMI.

The Faraday cage concept

- A “Faraday cage” is an enclosure made from conductive material to block electric fields. It shields the enclosed circuits from external EMI and stops any circuit-generated EMI from escaping.
- A fully-surrounding, grounded enclosure provides complete shielding, while one with holes in it can allow some EMI to come through.

Shielded enclosures

- Circuit boards generate EMI—and are also effected by it. Products with circuit boards are often shielded within metal enclosures that function as Faraday cages. When the enclosure is made of metal sheet or mesh (or painted with conductive paint) and connected to the reference potential (earth-ground), it behaves as a Faraday cage. Holes in the enclosure (for cables, buttons, indicators, etc.) allow EMI to leak out, and should be kept to a minimum.

Shielded cable

- In order to reduce EMI, cables are often provided with a shielding conductor, which creates an effective Faraday cage around the length of the cable. The shield is a metallic braid or spiral winding of metal foil or conductive plastic that surrounds the insulated signal-carrying conductors in the cable. A protective insulating jacket typically covers the shield layer.

Reference potential

- Shielded enclosures and cables usually are electrically-connected to the circuit’s return-signal path (circuit-ground). This may be quite different from the earth-ground potential, but, if the circuit-ground is also earth-grounded, the shield will be earth-grounded, too.
- Don’t connect both ends of a cable shield to “ground,” as this could result in an unwanted “loop” current to flow. Connect only the end that is nearest to the main circuit-ground potential.

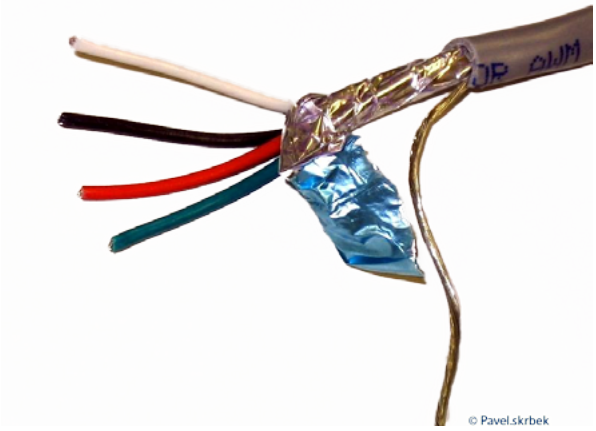
Broken shield connections

- In the case of having to troubleshoot EMI, it may be necessary to check for breaks in the cable shielding. This most often happens at or near the connector. Without a good reference potential (ground) connection, the shielding is less effective at dissipating EMI.

A Faraday cage in reverse: a microwave ovens blocks the escape of dangerous microwave radiation used in cooking

Note that the metal screen in the glass window also keeps radiation inside

Shielded co-axial cable is constructed so that the signal on the inner conductor can neither radiate nor receive EMI when the shields are grounded



Motor cables are typically wrapped in a foil ground-shield, which will typically be connected to the CNC Controller's internal ground

Understanding the service entrance ground

The power company provides an earth-ground for the transformer that supplies power to your service entrance. Your service entrance encloses current carrying “hot” wires, a return-current-carrying “neutral” wire, and a ground wire for each branch circuit, and it protects these with overcurrent-detecting circuit breakers. Also at the service entrance, the neutral wires and the ground wires are bonded (connected) together and to an earth-ground electrode.

Electrical service-entrance ground (green wire ground)

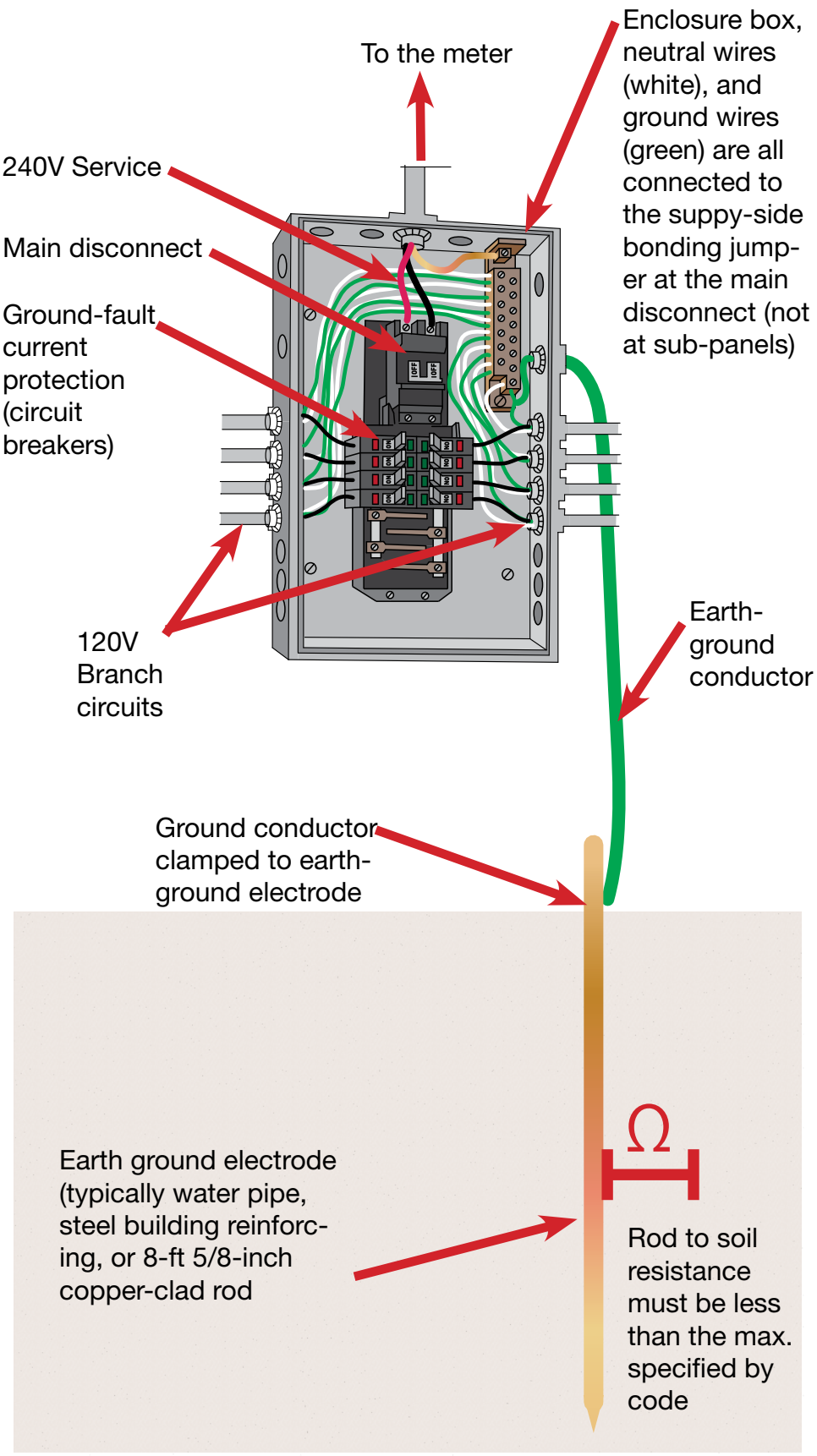
- At the main electrical disconnect (closest to the electric meter), you find the first division of conductors into branch circuits. Each branch is rated for its current-carrying capacity and is protected by an overcurrent device (circuit-breaker) that disconnects the “hot” wire if there is a short-circuit or other malfunction.
- Inside the service entrance enclosure, each branch circuit has its neutral conductor (current-carrying return path) and its ground wire bonded (electrically connected) together and bonded to a nearby earth-ground electrode (typically an 8-foot, 5/8” copper-clad rod driven into the earth).

Ground-fault current path

- To protect people from electrical shock during malfunctions, the service is designed to return the load current to its source through the neutral conductors or, alternatively, through the ground conductors which bond to the neutral at the service entrance.
- A ground-fault (short-circuit) causes a current surge in the ground-fault current path, quickly tripping the automatic overcurrent protection device (circuit breaker). This disconnects the ground-faulted branch from it’s “hot” (black) current-carrying conductor.
- The earth is not considered an effective ground-fault current path.

The service entrance ground can dissipate EMI, but additional grounds rods may be more effective—but, ONLY when advised

- While EMI may be dissipated through the branch circuit ground (green) wires, which are bonded to the earth ground electrode at the service entrance, this will generally only be effective when the branch circuit conductor lengths are fairly short.
- For EMI, additional short conductors bonded to additional ground-bus connections and additional earth-ground electrodes may be advised. See your qualified electrical workers or power company consultants for additional information you may require.
- If the use of additional earth-grounding connections results in objectionable current (per NEC 2011 250.6(B)) :
  - Discontinue one or more of the grounding connections
  - Change the grounding connection locations
  - Interrupt the objectionable current path
  - Take other suitable approved action



To reduce shop EMI, connect each equipment component (plasma cutter, welder, and electronic equipment) to an separate dedicated branch circuit

Balance these loads between circuits when possible

Always consult with a qualified electrical worker / contractor or a professional representative from your local power company to ensure code compliance

Creating a bonded (“star”) ground

Depending on the local code regulations, you may be allowed (or required) to help reduce EMI using a “star” ground—an earth electrode (ground rod) installed near the shop equipment. A “star” ground bus bar might be mounted to the table and bonded (connected) to the earth electrode and also to electrical enclosures, work tables, and work cables in the shop. This arrangement can provide a means of dissipating EMI. Always consult a qualified electrical worker before undertaking electrical modifications.

Consider a “star” ground

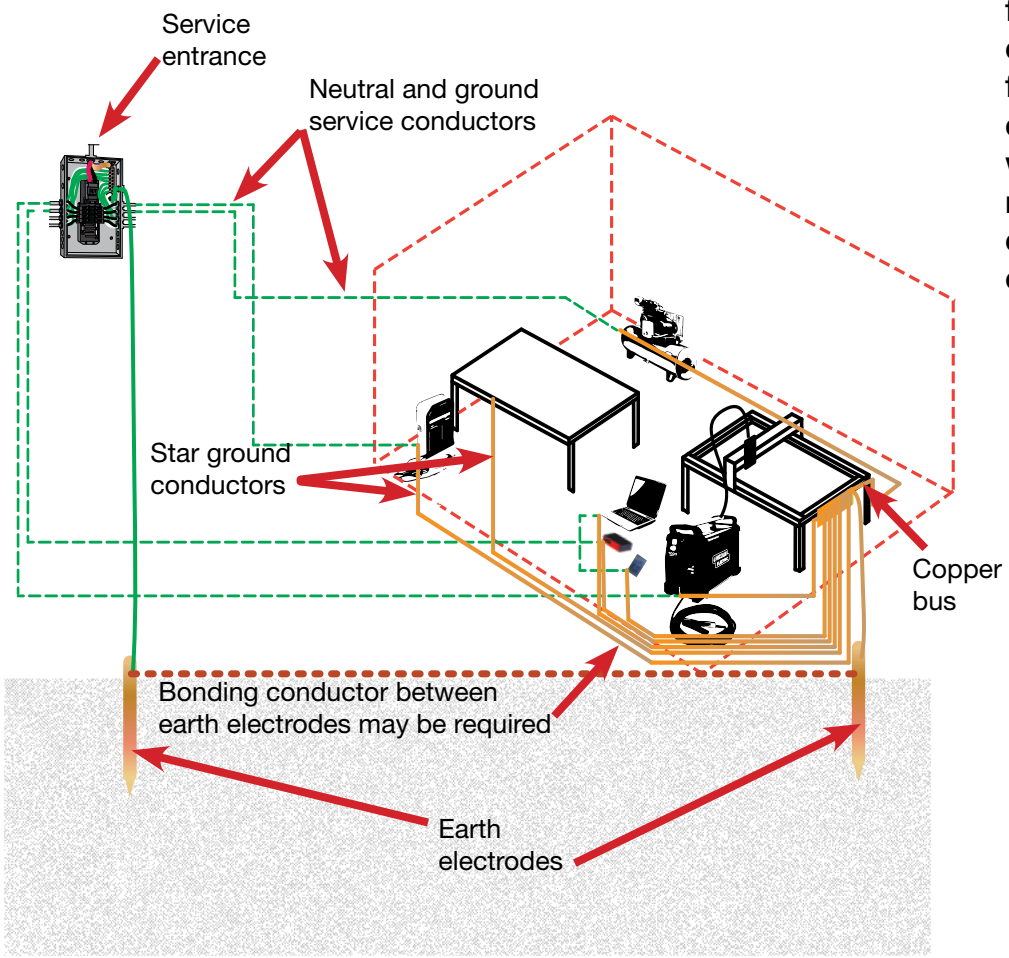
- To reduce EMI, your qualified electrical worker may advise the installation of an independent earth-ground rod and bonding all your welding and cutting tables, shielded cables, and electronic enclosures to it with heavy copper conductors, forming a star with all conductors connecting to a heavy bus bar.
- You may be required to run a from the local “star” earth-ground rod electrode to the service-entrance earth-ground electrode. Verify this with your qualified electrical worker / contractor.
- According to the ANSI Z49.1 Safety in Welding, Cutting, and Allied Processes, “11.3.2 The Work. The workpiece or metal upon which the welder welds shall be grounded, independent of the welding leads, to a good electrical ground, unless a qualified person assures it is safe to work on an ungrounded workpiece.” This would appear to apply to plasma cutting, but verify this with your qualified personnel.
- Ground rod installations are covered by NEC Section 250.

Earth- electrode to earth resistance

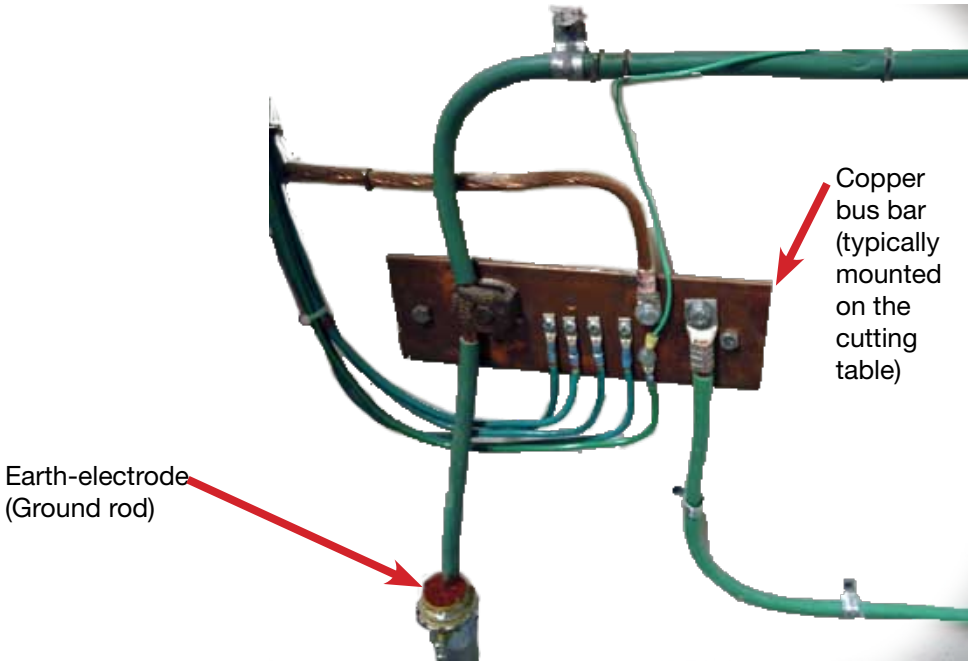
- The electrical resistance between the soil of the earth itself and the earth-ground electrode (or “ground rod”) determines the ability for the electrode to dissipate EMI. This resistance can be tested by a qualified electrical worker with the proper test equipment. It must be less than 25 ohms by code, and should be less than 5 ohms for a shop with electronic CNC equipment. If the resistance is too great, additional earth electrodes may be needed.

Ground to neutral voltage

- If the branch circuits in your facility are not balanced or there are other issues with the circuit layout, the voltage on the neutral conductor can differ from the ground (earth) potential.
- Test the voltage between the neutral conductor of your circuit and the ground with a good quality voltmeter.
  - The neutral to ground voltage measured should be less than 0.75 V.
  - Consult a qualified electrical worker if the voltage is too high.



A “star ground” is formed when parallel conductors are run from electronics enclosures, tables, and work cables to a common bus. The bus is connected to an earth electrode.



Conductors from tables, electronics encloures, cable shields, and work cables are all bonded to a copper bus, which itself is bonded to the earth electrode

All the conductors radiate from the bus like a “star”

Filtering out EMI

There are at least two types of filtering devices that can be used to reduce EMI in your shop. The *first* type is a simple ferrite choke in the form of a “donut” (torus) or “bead” (snap-on hollow cylinder). These can be added to any power, control, or data cable, to limit the RFI in the conductor. The *second* type is a battery-based inverter power supply. It uses the electrical service to charge batteries which then drive an inverter to change the battery’s DC back to 60 Hz 120V AC power for the electronics and computer(s). This is frequently called an “un-interruptible power supply,” or UPS.

Ferrite chokes

- Adding a ferrite donut or bead to cables will reduce the EMI intensity in a cable. Without being physically inserted into the current path, the ferrite choke acts like a resistance to attenuate only the high-frequency (EMI) components of the current.
- To install a ferrite donut, pass the cable connector through the center of the donut. Additional wraps through the center will increase the filtering action.
- Ferrite beads usually have a plastic shell and are made in halves with polished joining surfaces. To install a ferrite bead, open the plastic shell by releasing the side catch, insert the cable (close to the cable connector) into the revealed channel, and snap the shell closed.

Where to put ferrite chokes

- Put the ferrite donut or bead closest to the computer and electronics on any power or signal cable. Ferrite beads may already be molded onto the USB cable (as a cylindrical “lump”).

Battery / Inverter power sources (UPS)

- Some models of a battery / inverter power source (often known as an un-interruptible power supply, or UPS) break the direct connection of the protected equipment (typically the electronics boxes and the computer) from the electrical service during regular operation. This eliminates the current path for EMI to reach the electronic equipment through the electrical service.
- The UPS batteries are charged from the electrical service. The batteries then provide power to the electronic devices. Battery power is converted to a compatible AC voltage by the inverter.
- During a power failure, the battery / inverter continues to supply power so that a graceful shutdown can be done.
    - Note: *some products do NOT run on the batteries continuously, and switch to battery power only during a power failure. This kind of product will NOT protect your electronics from EMI during normal operation.*

	
Ferrite torus	Ferrite bead (open)
	
Ferrite bead (closed)	Molded in ferrite beads

Some different kinds of ferrite chokes

A UPS contains an inverter, a battery charger, and a switch, plus enough batteries to continue to run for a short time during a power failure

If the UPS model always supplies power through the inverter from the batteries, greater EMI immunity is achieved

Equipment selection

Some available shop equipment generates more high-frequency radiation than others. For example, many TIG welders will use AC / high-frequency to start and maintain their arc. Other types of equipment generate high-frequency, too. To minimize the EMI effect of this equipment, you may want to consider other purchase options of non-high-frequency equipment, or you may want to schedule CNC cutting at different times than when the high-frequency equipment is being used.

Evaluate equipment based on EMI produced

- Shops that regularly rely on CNC cutting and that also develop an understanding of the EMI produced by all of their equipment are better able to reduce the adverse EMI effects on their production.
- Just by considering EMI's effect on performance, shops will begin to identify which equipment is more likely to create issues. While it is possible to conduct a thorough investigation with sophisticated measurements, this is expensive and rarely required. Regular observation and care will usually be all that is required.

Choose equipment without designed-in HF

- When purchasing additional, upgraded, or replacement equipment, it can be very helpful to compare the potential of that equipment to produce EMI.
- For example, if one model of plasma cutter relies on a high-frequency arc starting circuit and a competing model does not, you may want to give additional consideration to the model that does not use high-frequency, as that is a potential EMI source.

Schedule use of HF equipment when not cutting

- If you find that certain equipment in your shop regularly generates HF EMI and causes issues with your CNC equipment, you may find the best solution is to schedule it's use when the CNC systems are not in use.
- This kind of compromise, while not ideal, can result, in some cases, in greater productivity at less cost than other measures.

Evaluate potential EMI produced

Avoid using high-frequency equipment whenever practical

Schedule as many HF generating tasks (like TIG welding) as possible to be done at different times than CNC plasma cutting