Ronnie's Electrical Notes

Author
Ronnie Coleinger

Publisher
Ronnie Coleinger Publishing

 This ebook provides guidelines for the safe use of electrical equipment. Please be certain to contact a licensed professional whenever working on electrical equipment. Common sense and proper electrical training are required when utilizing any information outlined in this document. Do take the time to perform proper Lock and Tag out procedures. Do it every time you work on electrical equipment. You are responsible for your life and welfare and of those people working around you. Do not shirk your responsibilities.

Table of Contents

Chapter 1 - Electrical Safety and the Working Electrician

As a working master electrical, I have had the opportunity to hear and witness many of the horrors that occur daily to electricians who continue to perform unsafe acts while working with equipment that utilizes electrical energy. It only takes one moment of inattention or one stupid act to kill you dead where you stand, or worse yet, burn you so badly you will wish you were dead. Those words sound harsh, but I personally know people who have had electrical equipment explode, or they touched energized electrical circuits. Many of these people were severely shocked and burned.

I have myself been severely shocked and could have died if I had not been paying attention to my environment and surroundings. When we work on electrical equipment, it is imperative that we work in a position that allows us to move our bodies or fall free of the source of power if we are shocked or the equipment explodes. I have personally had to pull a man down out of a metal grid ceiling and perform CPR to revive him. The man was fine once his heart restarted, but he could have died if his fellow workers had not been paying attention. I have been on the receiving end of 480-volt alternating current power, and I know how quickly it can render a man unable to save his own life. I had just purchased a new set of test leads for my voltmeter. I opened the package and put the new leads into the meter. I walked out to the panel I was working on, turned on the power, set the meter on the correct scale, placed the test leads on the energized terminals, and instantly felt the horrible feeling of 60-hertz power. I had placed my left knee on the edge of the panel for some reason, and when I touched the test lead tip to the panel terminal, the current flowed from my fingers, through my body, and out my knee to the grounded panel. I woke a couple moments later with three people hovering over me. I had flung my body free from the power source and my out of control muscles had hurled me backwards against a concrete block wall, some five feet behind the electrical panel. When my supervisor inspected the new test leads I had just used, he discovered a bare place on the wire where the insulation was not covering the twisted copper wire. My advice, inspect every test lead you own, including the new ones you purchase, because stupid shit does happen.

I was okay in a few minutes, but the incident taught me that we must pay attention to the stupid things we all do from time to time. I had never put my knee on a panel while working inside an energized panel, so why did I do it on this day. The words, careless work practices, come to mind. I have had other incidents of being shocked, but have learned how to insure I was in a position so I could clear myself quickly if I was shocked.

I have one comment to make, *Do Not Work on Energized Electrical Equipment*. Do take the time to perform proper Lock and Tag out Procedures. Do it every time you work on electrical equipment. I have included a copy of the Lockout Tagout Procedures for you to read. They are important. Please read them. Your life and those working around you are not worth taking chances.

SOP: General Lock and Tagout Procedures

Before working on, repairing, adjusting or replacing machinery and equipment, utilize the following procedures to place the machinery and equipment in a neutral or zero mechanical state.

Preparation for Shutdown

Before authorized or affected employees turn off a machine or piece of equipment, the authorized employee will have knowledge of the type and magnitude of the energy, the hazards of the energy to be controlled, and the means to control the energy.

Notify all affected Employees that the machinery, equipment or process will be out of service

Machine or Equipment Shutdown

Turn off or shut down the machine or equipment using the procedures for that specific machine. Utilize an orderly shutdown to avoid any additional or increased hazards to employees during equipment de-energization.

If the machinery, equipment or process is in operation, follow normal stopping procedures (depress stop button, open toggle switch, etc.).

Move switch or panel arms to "Off" or "Open" positions and close all valves or other energy isolating devices so that you have disconnected or isolated all energy sources from the machinery or equipment.

Machine or Equipment Isolation

All energy control devices used to control the energy to the machine or equipment will be physically located and operated in such a manner as to isolate the machine or equipment from the energy source.

Lockout or Tagout Device Application

Authorized employees must affix Lockout or tagout devices to energy isolating devices before work begins. They will affix Lockout devices in a manner that will hold the energy isolating devices to the "safe" or "off" position.

Where tagout devices are used they will be affixed in such a manner that will clearly state that the operation or the movement of energy isolating devices from the "safe" or "off" positions is prohibited.

Attach all tagout tags to the same point a lock would be attached. Locate the tag as close as possible to the lockout device so it is immediately obvious to anyone attempting to operate the device, if it is not practical to locate the tag with the lockout device.

Lock and tag out all energy devices by use of hasps, chains and valve covers with an assigned individual lock.

Stored Energy

Following the application of the lockout or tagout devices to the energy isolating devices, all potential or residual energy will be relieved, disconnected, restrained, and otherwise rendered safe.

Where the re-accumulation of stored energy to a hazardous energy level is possible, continued verification of isolation will continue until the maintenance or servicing is complete.

Release stored energy (capacitors, springs, elevated members, rotating fly wheels, and hydraulic/air/gas/steam systems) must be relieved or restrained by grounding, repositioning, blocking and/or bleeding the system.

Verification of Isolation

Prior to starting work on machines or equipment that have been locked or tagged out, the authorized employees will verify that isolation or de-energization of the machine or equipment have been accomplished.

Assure you will place no employee in danger and test all lock and tag outs by following the normal start up procedures (depress start button, etc.).

Caution: After Test, place controls in neutral position.

Extended Lockout – Tagout

If reassigning the task to the next shift, employees must lock and tag out before the previous shift may remove their lock and tag.

Chapter 2 - Resistor Color Code Chart

The information in this chart has not changed since the beginning of my electrical career. I have it in my notebook for easy reference in times of extreme stress. Those times occur when you are at a customer’s jobsite and need to replace a resistor in their copy machine, but cannot remember the color code. The owner has one of his employees standing beside you, waiting for you to write down the information so he can drive to the local Radio Shack store and purchase the required resistor. It is in those times that a mind seems to go blank on something as simple as a resistor color code. Therefore, here is the information in my notebook, to save your ass from embarrassment in your time of need. Aren’t you lucky you purchased this notebook?

RESISTOR COLOR CODING CHART

Color	1st band	2nd band	3rd multiplier
Black	0	0	x1
Brown	1	1	x10
Red	2	2	x100
Orange	3	3	x1, 000
Yellow	4	4	x10, 000
Green	5	5	x100, 000
Blue	6	6	x1, 000,000
Violet	7	7	x10, 000,000
Gray	8	8	x100, 000,000
White	9	9	not used

A fourth band indicates tolerance (Accuracy).

Gold = plus or minus 5%
Silver = plus or minus 10%
None = plus or minus 20%

If the first color band is wide, it indicates the resistor is a wire-wound type.

If the first color band is wide and there is a fifth blue band, it indicates a wire-wound type that is flameproof.

For radial lead tubular resistors, the first band is the tolerance, the body color is the 1st digit, the right color band is the 2nd digit, and the dot in the center is the multiplier.

Five band resistors (precision and mil-spec) or precision resistors, the first three bands are the significant figures. The fourth band is the multiplier. The space between the fourth and fifth bands is wider than the other bands, this helps identify the tolerance band.

On military type resistors, the fifth band indicates reliability information such as failure rate.

SIX BAND RESISTORS

Use the standard color chart for the first three bands. The colors are the same as those shown in the 1st band column. Fourth band, use the multiplier column from the color chart, along with these added colors. Silver = 0.01, gold = 0.1. For the fifth band, use these colors, gold = +- 5%, silver = +- 10%, none = +- 20%, brown = +- 1%, red = +- 2%, Green = +- 0.5%, Blue = +- 0.25%, and purple = +- 0.1%.

The Sixth band is the temperature coefficient. This band is spaced wide to the right. Brown = 100 ppm/k, Red = 50 ppm/k, orange = 15 ppm/k, yellow = 25 ppm/k.

The ppm/k is a value expressing a change in the resistors resistance value with a temperature change.

Here is an example of a six-band resistor color code with the color bands of, brown, black, black, black, brown and red. This would represent a resistor with the value of 100 ohms, 1% tolerance, 50 ppm/k temperature coefficient.

Chapter 3 - Resistor Digital Coding Information

The days of reading the value on many of the resistors we electronic technicians deal with on a daily basis, has changed drastically over the years. It used to be that you simply looked at the color bands, and within a matter of seconds, you knew the value and tolerance of the resistor. Those color bands are still in use today and probably will be for many years to come. Most of us older technicians memorized a catchy little saying about a girl named Violet to help us remember the sequence of the color bands (Bad Boys Rape Our Young Girls But Violet Gives Willingly).

However, times have changed a little. Today many of the resistors we see have a code made up of letters and numbers stamped onto the bodies. The code is simple enough to read once you get the hang of where to place the decimal point. I will give you a list of examples of the digital code stamped on the resistor and the value. From the list, you should be able to decipher most of the values you will ever encounter.

EXAMPLES OF DIGITAL CODING VALUES

The letter "R" designates the decimal point location (this is important)
The letter "K" designates a multiplier of 1000 (K = kohm stands for 1000)
The letter "M" designates a multiplier of 1,000,000
(M = megohm stands for 1,000,000)

Just a note: Don't let the letters K, M, and F confuse you. These letters may also designate a tolerance code for the resistor, and I will show you that later.

0R22 = 0.22 ohms
1R0 = 1.0 ohms
10R = 10 ohms
22R = 22.0 ohms
47R = 47.0 ohms
47R7 = 47.7 ohms
2K2 = 2200 ohms (2.2 x 1000)
3K9 = 3.9 kohm (3.9 x 1000)
2M2 = 2.2 megohms (2.2 x 1,000,000

Now let me show you how they add the tolerance codes to the value codes I have already shown you.

The letter "B" at the end of the code represents a tolerance value or 0.1%.
The letter "C" = 0.25%.
The letter "D" = 0.5%.

The letter “F” = 1%.
The letter “G” = 2%.
The letter “J” = 5%.
The letter “K” = 10%.
The letter “M” = 20%.

Now for some more examples:

R33M = 0.33 ohms (The M = 20% tolerance)
4R7K = 4.7 ohms (The K = 20% tolerance)
6K8F = 6.8 kohm or 6800 ohms (The F = 1% tolerance)
4M7M = 4.7 megohms or 4,700,000 ohms (The M = 20% tolerance)

By now, you should have a good understanding of the coding for many of the resistors you will run across in your everyday electronics work.

ANOTHER CODING METHOD I HAVE DISCOVERED

I have discovered another coding method in use from some overseas suppliers. Here is how the code works. It is really quite simple.

If you see a number 101 stamped on the body, it means 100 ohms. The last number 1 tells you how many zero’s to add after the first number. The letter “R” still represents the placement of the decimal point as it does in the preceding code I explained to you. Here is a list of common values:

1R0 = 1.0 ohm
10R = 10 ohms
101 = 100 ohms
472 = 4700 ohms = 4.7 kohm
683 = 68000 ohms = 6.8 kohm
1002 = 10000 ohms = 10 kohm
223 = 22000 ohms = 22 kohm
224 = 220000 ohms = 220 kohm

The code I just explained is very simple and very user friendly. That is all there really is to the digital coding systems. Hope this information helps you sort out your stash of resistors so you can sort them and put them into your usable inventory of parts.

Chapter 4 - Capacitor Coding Reference Chart

Many times, you will discover a capacitor with a digital valve stamped on the body instead of color codes. The following charts should help you determine a value for the capacitor.

Note: You may find a letter used in place of a decimal point. An example would be 2R2, which would equal 2.2 (pf or uf). Here are a few examples of digital coding values.

151K = 15 x 10 = 150 pf.
759 = 75 x .01 = 7.5 pf.
2R2 = 2.2 (uf or pf)

I will use the example of 151K for the following explanation. This is how to determine the values of this capacitor.

The first number shows the first digit of the capacitors value (1).

The second number shows the second digit of the capacitors value (5).

The third number shows the multiplier. Simply multiply the first two digits by the value shown in the table below. In this case, the number is (1), so the multiplier is 10. So if we work the simple math, 151 = 15 x 10 = 150 pf.

The letter at the end of the number (K), in this example is the tolerance of the capacitor. You can look up the value on the tolerance chart that follows, but the value is 10%. Ten percent of 150 would be 15. The tolerance of the capacitor would be 135 pf on the low end, and 165 pf on the high end. A capacitor meter would give you the exact value if you needed to be very accurate in determining the exact value.

Chapter 5 - Sinking and Sourcing

Do You Feel Confused?

I have trained many electronics technicians and electricians how to wire and work with direct current sensors and programmable logic controller inputs, and outputs. Here is what I have learned over the years that may help you the next time you get confused.

WORKING WITH D.C. SENSORS AND MODULES

When working with direct current sensors, remember the saying, “Mr. Brown is always positive.” That saying is always in the back of my mind and is an important saying to memorize. When you begin wiring any sensor, remember that the brown wire always connects to positive power, the blue wire always connects to negative power, the black wire is the normally open lead, and the white wire is the normally closed lead.

Direct current sensors and component amplifiers use a transistor for their output switch. There are three output configurations presently used in the industry, they are:

Open collector NPN transistor - current sinking.
Open collector PNP transistor - current sourcing.
Isolated NPN - current sinking or sourcing

Current sinking outputs switch ground (DC common). The load connects between the sensor output and the positive supply voltage.

Current sourcing outputs switch positive DC to the load. The load connects between the sensor output and the negative supply voltage.

NOTES FOR THE ABOVE INFORMATION

Remember that current always flows from negative to positive. When you look at a drawing for the sensor you are working with, you need to understand the following statements:

An NPN transistor has the arrow pointing away from the base. A PNP transistor has the arrow pointing towards the base. This is always true, always!

NAMUR SENSORS

Namur sensors are a 2-wire, variable resistance, direct current sensor which requires a remote amplifier for operation. Typically, this we use these sensors for intrinsically safe applications. Now you are going to ask what intrinsically safe means, and I was ahead of your question. Intrinsically safe is a protection technique for safe operation of electronic equipment in explosive atmospheres. Engineers originally developed the concept for safe operation of process control instrumentation in hazardous areas. Today, there are hundreds of other uses for this technique, but the original design concept is still valid.

SOURCING AND SINKING PLC INPUT MODULES

Identifying sinking PLC input modules is easy once someone has explained the concept to you. Here is everything you ever wanted to know in just a few words.
The negative DC voltage goes to the DC COM (common) terminal.
The positive DC voltage goes to each input terminal.

You would be switching a positive voltage or using a sourcing sensor to feed the input terminals.

Identifying sourcing PLC input modules is just as easy. Let me explain what will determine this input method.

Positive DC voltage goes to the VDC terminal.
Negative DC voltage goes to each input terminal.

You would be switching a negative voltage or using a sinking sensor to feed the input terminal. I realize this is difficult to comprehend the first few times you deal with it, but you will soon get the hang of it. Until then, keep this reference sheet available in your toolbox.

IDENTIFYING SOURCING TRANSISTOR OUTPUT MODULES

Positive DC connects to the VDC terminal.
Negative DC connects to DC COM (common) and common of loads.
Terminal marked; OUT 0-15 is the positive voltage to loads.

IDENTIFYING SINKING TRANSISTOR OUTPUT MODULES

Positive DC connects to VDC terminal and common on loads.
Negative DC connects to DC COM (common).
Terminal marked; OUT 0-15 is negative voltage to loads.

Note to remember: PLC outputs match the configuration for sourcing and sinking sensors.

I hope this reference sheet helps you. I have worked with many electricians and electronic technicians that never really understood the concept of sinking and sourcing. Understanding this concept will help you immensely whenever you find yourself confronted with a sensor that needs to feed a programmable logic controller input.

Chapter 6 - Electronic Sensors – Not with Relays

Authors comment: Never put mechanical contacts in series with a photo eye or proximity sensor.

If you have ever tried to put an electronic proximity switch or a photoelectric sensor in series with a circuit containing mechanical relay contacts, you know by now that all sorts of problems can arise. You should always avoid placing mechanical relay contacts in series with a proximity switch, as they create an open circuit, leaving the sensor without power.

In order for electronic sensors to operate properly, they need continuous power. You can create a real problem for yourself when the mechanical contacts open and remove power to the sensor. When the contact recloses, restoring power to the sensor, there will be a short time delay before the sensor is ready to function. This time delay actually has a name, *Time Delay before Availability*.

SOLUTION

When using a 120-vac power source, you can add a 33K ohm 1-watt by-pass resistor across the mechanical contact to eliminate the time delay before availability issue. This resistor will allow enough leakage current to flow around the open contacts to keep the sensor ready for instantaneous operation. You can calculate the resistor values for other voltages by using the minimum operation voltage and load current values shown in the sensors specifications sheet. Then by using simple ohms law, R=E/I, you can calculate the resistor value. However, remember that the best solution to this problem is not using the sensor and the mechanical contacts in series. Often times, you can work out an alternative solution to this problem. The best solution is to redesign your circuit so the sensor remains powered.

PROBLEM – Mechanical contacts in parallel with a sensor.

As we previously discussed, we should power sensors continuously to avoid the time delay before availability problem. With normally closed mechanical contacts in parallel, you virtually place a short circuit across sensor each time the contact is closed, leaving the sensor without power. If the target is present when the mechanical contact opened, we will experience a short delay during which time the load may drop out.

SOLUTION:

The best solution to this problem is to feed a separate relay coil with the sensor and then place the normally open contacts of the relay in parallel with the mechanical contacts.

Once again, I would like to stress that in most cases, the wiring can be altered to prevent the situations explained above from every becoming an issue, even if we need to add a relay into the circuit to remedy the problem.

Chapter 7 - Diode Applications

It may sound silly, but it seems that many technicians still don't know which end of a diode is the cathode and which is the anode. Here is an explanation that will help you with this task.

The symbol for a diode is an arrow pointing towards a flat bar. Remember that electron current flows against the arrow. The symbol dates back to the days when conventional current flow was in common use. Originally, the engineers thought current flowed from positive to negative, which would have been with the arrow.

If the diode has a band or two on one end, that end is the cathode.

If the diode is a ceramic bead type, which looks like a teardrop, it should have a band on one end. The banded end is the cathode.

If the diode is tubular and one end is rounded, the rounded end will be the cathode.

If the diode is a metal can (top hat) style, the brim end is the anode, and the top of the stovepipe is the cathode.

For an LED, the flat side or the short lead is the cathode.

If you still are not sure which end is the cathode, you can simply use an ohmmeter to locate the cathode. Place the meter's red (positive) lead on one end of the diode and the black (negative) lead on the other end. Observe the meter reading, and then reverse the meter leads. One direction will give a lower meter reading. When you have the leads on the diode and reading the lower meter reading, the black meter lead will be on the cathode of the diode.

Hope this helps you the next time you discover a diode or LED that you cannot find the correct polarity for, pull this handy sheet out of your toolbox.

Chapter 8 - Diode and Semiconductor Color Coding

Germanium and some other diodes use a color code much like resistors to determine their identity. The end of a diode that the color band is closest to is the cathode end. From the cathode end, read the first three or four digits, followed by the suffix letter if one is used.

NUMBER	COLOR	SUFFIX LETTER
0	BLACK	N/A
1	BROWN	A
2	RED	B
3	ORANGE	C
4	YELLOW	D
5	GREEN	E
6	BLUE	F
7	VIOLET	
8	GRAY	
9	WHITE	

The letter following the letter "N" of the "1N" diode series is indicated by color bands. The first band may be double width or all bands may have equal width. On a four-digit diode, if no suffix is used, you may find the fifth band to be black.

Chapter 9 - Transistor Identification

This article will give you an insight into how to work with the common NPN and PNP transistors that you find on most electronic equipment, and stashed in your spare parts bins. I will explain the proper bias for both versions of the common bipolar transistors in order to help you troubleshoot them, and then explain how to use an ohmmeter to identify to two versions, NPN and PNP.

TRANSISTOR BIAS RULES

PNP bias rule…The voltage on the base is more negative than the emitter is, and the collector is more negative than both are.

NPN bias rule…The voltage on the base is more positive than the emitter is, and the collector is more positive than both are.

The rule is simple enough. The collector-base junction must always be reverse-biased, and the emitter-base junction forward biased. You have connected Vcc correctly in every case if the polarity of the lead going to the collector is opposite the type of collector material. That is, in an NPN transistor, the collector is negative, and fed from the positive terminal of Vcc. In a PNP transistor, the collector is positive and connected to negative Vcc.

For the emitter-base bias, connect P type material to positive Vcc and negative material to negative Vcc.

TRANSISTOR IDENTIFICATION

This test establishes the base lead as the one that is not involved in the higher forward resistance reading.

You will observe a low ohmmeter reading (below 500 ohms) when the meter places a forward bias across the emitter-base junction.

You will obtain a higher reading when the meter places a forward bias across the emitter-collector junction.

BRIDGE RECTIFIER MODULE TESTING PROCEDURES

POSITIVE LEAD	NEGATIVE LEAD	AC	AC	RESULTS
BLACK		RED		LOW RESISTANCE
BLACK			RED	LOW RESISTANCE
RED		BLACK		INFINITE RESISTANCE
RED			BLACK	INFINITE RESISTANCE
	RED	BLACK		LOW RESISTANCE
	RED		BLACK	LOW RESISTANCE
	BLACK	RED		INFINITE RESISTANCE
	BLACK		RED	INFINITE RESISTANCE

In the table above, the red meter lead is positive and the black lead is negative.

IDENTIFYING TRANSISTOR GENDER TYPE

Use this method to determine the type (NPN or PNP) of a transistor you are dealing with. Take an ohmmeter reading between the base and emitter or base and collector. If you obtain a low resistance reading with the negative lead of the meter connected to the base, the transistor is a PNP type. A low resistance reading when the base is positive indicated an NPN type.

NPN AND PNP SYMBOL IDENTIFICATION

NPN identification…The arrow IS NOT POINTING toward the base.
PNP identification…The arrow IS POINTING towards the base.

Chapter 10 - Working with 555 Timers

I have assembled some notes to help you when you are working with 555 integrated circuit timers. Once you understand the quirks of the timers, they are a very stable platform for designing all kinds of timers and counters. I will begin with a brief explanation for the operation of the timer.

OPERATION

Applying a negative pulse to the reset terminal (pin 4) during the timing cycle discharges the external timing capacitor and causes the cycle to start over again. The timing cycle will now commence on the positive edge of the reset pulse. During the time the reset pulse is applied, we drive the output to low state. When the reset function is not in use, connect pin 4 to Vcc to avoid any possibility of false triggering.

TROUBLESHOOTING FALSE TRIGGERING PROBLEMS

Add a 0.1 MFD disc capacitor and a 1.0 MFD tantalum or electrolytic from pins 1 and 8 as close to the 555 as possible.

Also, add a .01 MFD capacitor from pin 5 to ground and add a .1 MFD capacitor from pin 5 to ground.

To prevent false triggering, be sure to dress any alternating current wires or sources well away from any wires that may leave your printed circuit board that contains direct current or timing signals. Here is a test of stability. If you touch pin 2 with your finger and the 555 triggers, try pulling up pin 2 to B+ with a 10K ohm resistor. Then when you pull pin 2 low, the 555 should trigger normally.

Anytime you have long leads for pin 2, like if you run out to a start relay or switch, always pull pin 2 high after the timing starts.

I have found that when running the 555 in the monostable mode (as you would for a timer), that the timing components values can differ with different versions of the timer. For a standard 555, use the formula T=1.1 RC. For the NE555 version use the formula T=.60 RC.

Hope this information helps the next time you have to deal with an unstable 555 timer.

Chapter 11 - Unused

Chapter 12 - Editing a Ladder Diagram in Paint

Sometimes when you are working with a ladder diagram, say in Allen Bradley or Siemens software, you may need to write comments and send them to someone via email or some other form. Sometimes you simply need to make comments on the diagram and save a copy for later use. Editing anything displayed on your computer screen is simple once you understand the method.

Here are the steps I often use to produce these documents.

With the ladder diagram displayed on your computer screen, press and hold the ALT key and then press the PRINT SCREEN button on your keyboard. Then close or minimize the display on your screen.

Open a session in Microsoft Word. Click on EDIT and then click on PASTE. The screen print image will paste into the Word document. This step moves the screen print image into a Word document so you have a platform to work. I suggest that you save the Word document into a file to hold it while you do the next few steps. You will need to remember where you saved the document because you will need to paste from it when you enter the Paint program. The next step will then move the word document into the paint program where you can edit it, then allow you to return the document to Word where you can save, print, email, or do whatever you want with the edited document.

To move the document from Word into paint, follow the next steps. Right click inside the picture in the word document, and then click on COPY. Open the Microsoft Paint program and click on edit, then click on PASTE FROM. The paste will come from the file where you saved the program in the preceding step. Your screen print image will now appear in the Paint Program.

Here is the method I use to edit a ladder diagram and put notes on it for someone to review or for your own use. On the left side of the Paint screen, I click on the paintbrush tool. Then I move over to the image, click, and hold the left mouse button. I circle the part of the image that I want to identify, and then release the mouse button. Now if you click on the FILE in the left-hand corner, you can save the image to your hard drive and name it with whatever name you choose. Remember where you saved the image, as you will need it in the next step. Note: you can also create a text box in Paint and put notes inside the box if you wish, or you can wait until a later step and put the information in with Microsoft Word.

This final step allows you to insert the saved image back into a Word document where you can add comments and notes about the areas of the ladder or image you circled in paint. Here we go. Open a new Microsoft Word document and click on INSERT, then PICTURE FROM FILE. Locate the file where you saved the document with the circled areas of the image and click on INSERT in the bottom right hand corner. You can now add any text you want above or below the image to explain the circled areas that you created in Paint.

This involves a few steps, but works well when you need to pass information along, say to an engineer, or to a colleague in your office. You can even email the word document if you attach the file into the email program.

Chapter 13 - Conductor Temperature Ratings

Special Note: The 2005 NEC requires you to use the 75 deg. Fahrenheit column on table 310-16 for all lugs used to connect wires together or to utilization equipment.

Remember that the neutral is a current carrying conductor.

NEC ARTICLE, 310-10 – Temperature limitations of conductors.

No conductor shall be used in such a manner that its operating temperature will exceed that designated for the type of insulated conductor involved. In no case shall conductors be associated together in such a way with respect to type of circuit, the wiring method employed, or the number of conductors that the limiting temperature of any conductor is exceeded.

Most terminations are normally designed only for 60-degree C (140 deg. F) or 75 deg. C (167 deg. F) maximum temperatures, although some are now being designed for 90 deg. C (194 deg. F); therefore, the higher rated amenities for conductors of 90 deg. C, 110 deg. C, etc, cannot be utilized unless the terminations have comparable ratings.

Tables 310-16 through 310-21 have ampacity correction factor tables for ambient temperatures that are greater or less than the ambient temperature identified in the table heading. To assign the proper ampacity to a conductor in an ambient above 30 deg. C, the appropriate correction factors must be used. This correction factor is applied in addition to any devoting factor, such as in note 8a to tables 310-16 through 310-31.

Example: No. 2 AWG TW copper conductors are to be installed in a raceway in an ambient temperature of 50 degrees C. According to table 310-16, the ampacity of the conductor at 30 deg. C is 95 amps which is multiplied by 0.58 (taken from the correction factors at the bottom of the table); thus, the ampacity of the No. 2 conductor at 50 deg. C is reduced to 55.1 amps (95 amps X 0.58 = 55.1 amps)

If we ran six of these conductors in a raceway, Note
8a to the tables would require the ampacity to be reduced to 80 percent, which, in this case, would be 55.1 amps X 0.8 =44.08 amps. Under these conditions, the No. 2 conductors would be suitable for a 40-amp circuit.

The temperature rating of a conductor (see table 310-

13), is the maximum temperature, at any location along its length, that the conductor can withstand over a prolonged time period without serious degradation.

Conductors that have a rating above the anticipated maximum ambient temperature should be chosen. You should control the operating temperature of conductors at or below its rating by coordinating conductor size, number of associated conductors, and ampacity for the particular conductor rating and ambient temperature. All tabulation should be corrected for the anticipated ambient using the ampacity correction factors at the bottom of the tables.

Where more than three conductors are associated together, you should apply the additional corrections given in note 8a to the tables.

Note: When using conductors shown with an obelisk symbol next to them in table 310-16, use the higher amperage rating to start your calculations, and not the reduced value shown at the bottom of the page in the footnotes. Example; #12 THHN is shown as 30 amps in the table, so start your calculations with the 30 amps and not the 20 amps expressed in the footnotes.

Chapter 14 - Circular Mils Calculations

Every electrician has struggled to determine the proper wire fill for a conduit, junction box, or a pull box at some time in his or her career. Working with circular mils and square inches is very easy once you master a good understanding of what you are attempting to calculate. First, let me give you a tiny bit of background about the meaning of the words and their values.

For copper, aluminum, or copper-clad aluminum conductors up to size number 4/0, the code uses the American Wire Gage (AWG) for size identification, which is the same as the Brown and Sharpe Gage (BS). Conductors larger than 4/0 are sized in circular mils, beginning with 250,000 circular mils. Prior to the 1990 edition of the National Electrical Code, a 250,000-circular mil conductor was labeled as 250 MCM. In the 1990 code change, the notation was changed to 250 kcmil. The term MCM was originally defined as 1,000 circular mils (M is the Roman numeral designation for 1,000). The notation was changed to recognize the accepted convention that “k” indicates 1,000. ANSI/IEEE standard 100-1988, the IEEE standard dictionary of electrical and electronic terms, fourth edition, recent UL standards, and the new IEEE standards now use the notation kcmil, rather than MCM. So, there you have it, the letter “k” is now used to represent 1,000 in calculating wire sizes, as well as in sizing resistors; remember the kohm?

The circular mil area of a conductor is equal to its diameter in mils squared (1 inch = 1,000 mils).

Example #1

The diameter of a number 8 solid conductor is 0.1285 inches. 0.1285 in. x 1,000 = 128.5 mils. 128.5 x 128.5 = 16,512.25 circular mils. Rounded off, it would be 16,510 cmils (see table 8 of chapter 9 in the National Electrical Code. This represents the circular mils area for one conductor. Where stranded conductors are used, the circular mil area of each strand must be multiplied b the number of strands to determine the circular mil area of the conductor (see table 8 of chapter 9 in the NEC).

Example #2

The area of a circle can be expressed in circular mils by squaring it diameter expressed in thousands. Since 3/8 inch equals 375/1000 (.375), the area of a circle 3/8 inch in diameter would be 375 times 375 which equals 140,625 cmils. The area of a circle 0.005 inches in diameter would be 5 times 5, which equals 25 cmils.

To reduce square inches to circular mils or circular mils to square inches, apply these formulas.

Cmils = inches squared / .7854

Inches squared = cmils x .7854

Example #3

500 kcmil THHN wire is being used. Need twelve of them in a gutter. Find what size gutter is needed to hold them.

Diameter of 500 kcmil = .955

.955 X .955 = .912 sq. in. x 12 conductors x .7854 = 8.59 sq. in.

To calculate gutter sizes: 6 in. X 6 in. gutter has 36 sq. in., so 36 sq. in. times 20% fill would be 7.2 sq. in. This gutter is too small.

8 in. x 8 in. gutter has 64 sq. in., so 64 sq. in. time 20% fill would be 12.8 sq. in. This gutter will so nicely.

Metric Conversion Notes

To convert inches to mm, multiply inches times 25.40.
To convert mm to inches, multiply mm by 0.03937.

General Note to Conductor sizes

When you run across a conductor that does not have its diameter listed in the code tables, or you do not know what type of insulation it is. Simply measure the outside diameter. Then use the formula shown below to calculate wire fill. Use the 40% fill table shown above to work out the problem.

Diameter x diameter x .7854 = square inches for one wire. For multiple wires, use the following formula.

Diameter x diameter x l7854 x (# of wires) = sq. in. for all wires.

There you have it. All this time you thought circular mils calculations were difficult. Keep this notebook handy in your toolbox and your life will become much easier.

Chapter 15 - Torque Chart for Electrical Equipment

Scope: I developed this torque chart to assist electricians in properly tightening electrical connections on the electrical equipment found in everyday use throughout the industry. This chart, while tested carefully, should never override the instructions supplied by the manufacturer, or installation authority. Always consider the manufactures instructions for the equipment to be the final rule.

Note: 1-foot pound (ft. lbs.) equals 12-inch pounds (in. lbs.).
Note: The use of the term MCM has been replaced with the term Kcmil

BOLTED WIRE CONNECTIONS (Crimped on end lugs)

Bolt Size	Torque (in. lbs.)
1/4 x 20	70
5/16 x 20	120
3/8 x 16	225
1/2 x 13	375

LUG TYPE CONNECTIONS (Used on contactors, etc.)

Wire Size	Torque (in. lbs.)
#14 to #8	70
#6 to #4	100
#3 to #1	120
1/0 to 2/0	150
3/0 to 200 Kcmil	210
250 to 400 Kcmil	260
500 to 750 Kcmil	300

SCREW CONNECTORS (Used on instruments, oil tight operators, etc.)

Wire Size	Screwdriver Slots or wrench (In. lbs.)	External Drive (In. lbs)
#14	25	70
#12	25	70

#10	25	70
#8	30	75
#6	35	100

ALLEN HEX HEAD SOCKET SCREWS

Socket Size	Torque (in. lbs.)
1/8	35
5/32	80
3/16	100
7/32	120
1/4	150
5/16	225
3/8	300
1/2	400
9/16	500

ELECTRICAL BOLT TORQUE

Bolt Diameter	Torque (in. lbs.)
3/8 lubricated	180
1/2 lubricated	300
5/8 lubricated	480

Note: Use Penatrox or equal joint compound for lubrication.

BELEVILL (Conical) WASHERS

Bolt size	Diameter	Thickness
1/4	11/16	0.050 inches
5/16	13/16	0.060
3/8	15/16	0.070
1/2	1 3/16	0.085
5/8	1 1/2	0.100

Note: Belleville washers are sometimes called conical washers. They have no set torque value, but we often use them to prevent electrical connections from loosening when the connection may encounter temperature extremes or vibration that would loosen other types of fasteners. Tighten these spring type flat washers until they just flatten out and then leave them alone. The reason we torque electrical hardware is to insure it remains tight while in use. These washers serve the same purpose as using a torque wrench.

AMP RATINGS FOR BOLTS

Bolt Size	Current Carrying Capacity (amps)
3/8 inch	225 amps
1/2 inch	300 amps
5/8 inch	375 amps
3/4 inch	450 amps

STANDARD HEX HEAD BOLT TORQUE VALUES (SAE)

Bolt size	Grade 5
1/4	10 (ft. lbs)
5/16	14
3/8	25
7/16	40
1/2	60
9/16	88
5/8	120
3/4	200
7/8	302
1	466

I hope this chart helps the next time you document an electrical installation, or simply to reassure yourself that you have properly tightened the connections.

Chapter 16 - Buck – Boost Transformers

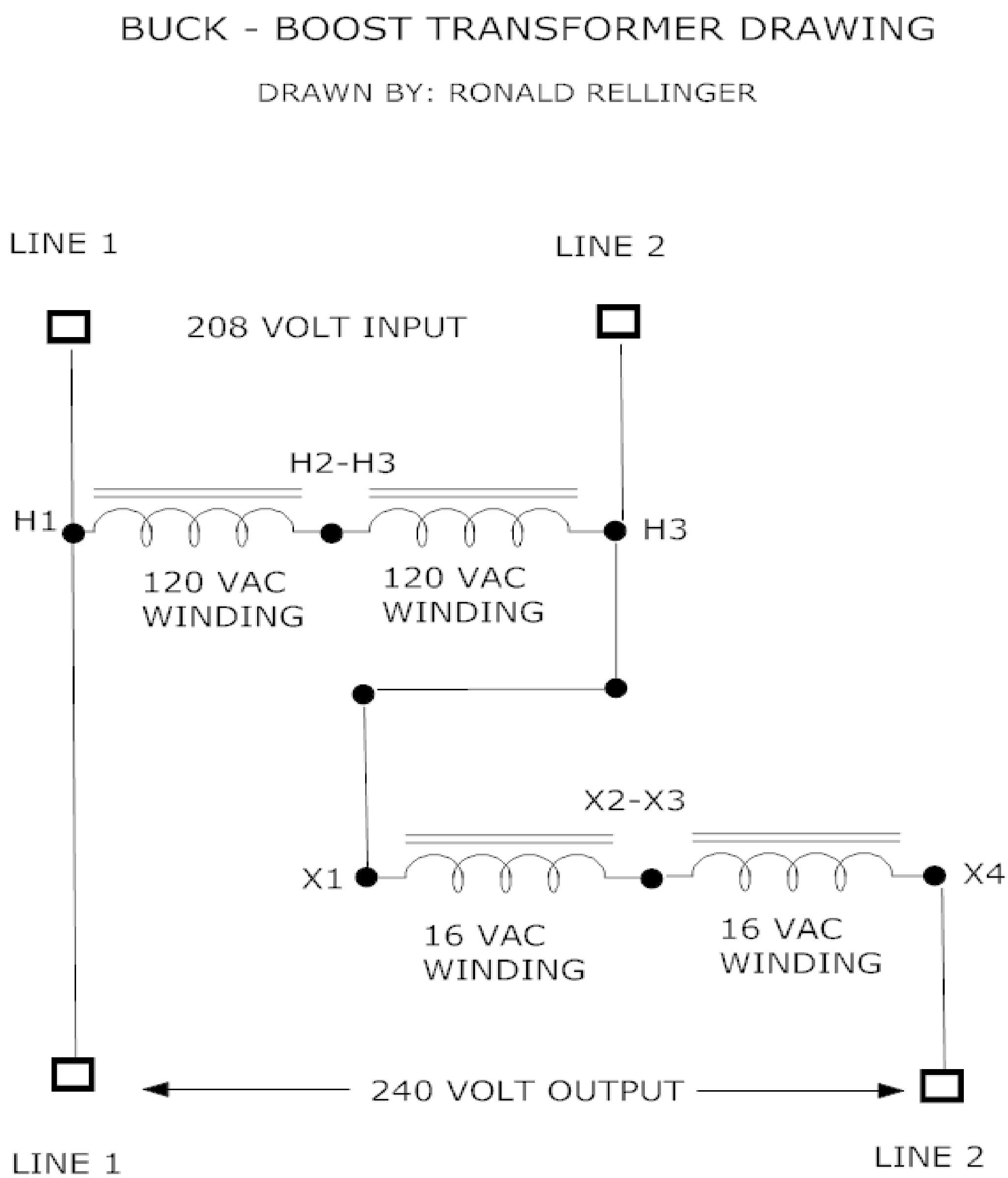
As an electrician, working with transformers can often times be a challenge. Over the years, I have had the opportunity to work with many others that were attempting to wire a transformer, and struggled with the project. One would think that following the wiring diagram on the cover of the transformer should not be so difficult. Usually the task is simple, and very little thought is required other than to insure the transformer is properly grounded, the proper disconnecting means are installed, and the neutral is connected to the proper terminals and is bonded per the requirements of the National Electrical Code. The challenge occurs when a standard transformer does not give the voltage required in an industrial or commercial application. Normally when a three-phase wye connection is used, the secondary of the transformer produces 208 volts alternating current on the secondary. If the voltage is being used for normal loads such as lighting, it makes little difference if the voltage is 208 volts or 230 volts. The catch is that some industrial and commercial equipment operates better when connected to 230 or 240 volts instead of 208 building power.

Recently, a customer called me to a jobsite because the induction heating system they had purchased would not produce sufficient heat to seal an aluminum cap on a plastic bottle of vegetable oil. They returned the equipment to the manufacture to be tested and they discovered that it worked correctly at their location. The manufacturer of the induction heat system then requested voltage measurements at the customer's location and discovered that the voltage supplying the heat system was 208 volts instead of the required 240 volts. The customer contacted me and asked if there was a way to get the correct voltage to the heat system without purchasing an expensive transformer for their main electrical service. When I arrived on the job and investigated the problem, the solution was obvious. All they needed was an inexpensive Buck-Boost transformer wired into the induction heat system to raise the building 208-volt voltage to the required 240 volts needed by the heat system. I purchased a transformer with a 208/240 volt primary, which had a multiple secondary capable of supplying 16 or 32 volts. I then wired the secondary windings in a boosting autotransformer arrangement to add 32 volts to the buildings 208-volt power to supply 240 volts to the machine. To make the story short, the induction heat system then worked as the manufacturer had advertised, with a little extra power to spare.

I have included a copy of the drawing that I used to add this Buck-Boost system to the customers machine. Just so you understand, if the customers building voltage had been too high, say 240 volts and they had wanted 208 volts, I could have reversed the X1 and X4 connections and the transformer would have bucked the incoming voltage to lower the 240 volts down to the required 208.

Another advantage of using a Buck-Boost transformer wired in this autotransformer arrangement is that the wattage of the Buck-Boost transformer can be much less than a standard transformer. When used as an autotransformer arrangement, the Buck and Boost unit will carry loads in excess of its nameplate rating. When you wire a transformer as an autotransformer, only the portion of the KVA that is bucked or boosted is used in determining the KVA rating. If a Buck-Boost transformer is wired for a 10% voltage boost, only 10% of the KVA is passed directly from the source to the load. The balance of the power passes straight from the source to the load and is not transformed. Therefore, the KVA rating of the Buck-Boost transformer is only one-tenth the KVA capacity of the standard transformer that would normally be required.

Below, you will find the drawing I created to help you understand the wiring method I used to boost the voltage to the induction heater I was working on.



Buck - Boost Transformers - Figure 1

Chapter 17 - Fuse Protection

TERMINOLOGY

FLA – Full Load Amps…The largest load current that the load is designed to carry under normal operating conditions.

Overload Current – Most often in the range of one to six times the rated full load amps of a device or system.

Short Circuit (Fault Current) – Fault currents can become extremely high during a short circuit event. They can and often times do run up into the 200,000-amp range. Three principle faults lead to the event. They are phase-to-phase, phase-to-ground, or phase-to-neutral short circuits. Once a fault is established, all three of the above may come into play as plasma develops and envelops the device. Plasma is a highly conductive vapor that contains particles of the materials that melted due to extreme heat. The plasma vapor will quickly short all current carrying conductors within the device, panel, or enclosure. It is the remains of the plasma cloud that one sees inside an electrical panel after a major electrical short circuit occur within its interior.

Current Limiting – This ability of modern fuses to cut off the flow of short circuit current within one-half cycle or less to prevent the short circuit currents from rising to a destructive peak level.

Fuse Interrupting Rating – This rating is expressed as (AIC), which stands for, amps interrupting capacity. Remember that modern fuses have two amperage ratings stamped on them. One is the normal amperage value, and the other is the interrupting value shown as AIC.

SELECTIVE COORDINATION – Prevention of Blackouts

It is important to select fuses throughout the power system of a facility to prevent the failure of one device from shutting down the entire facility. When only the protective device nearest a faulted circuit opens and larger upstream fuses remain closed, the protective devices are considered coordinated.

INFORMATION ABOUT FUSES

Fuses are devices used as over current protection. They operate because of the heating effect associated with electrical current flowing through the fuse link.

Fuse size considerations must be based on RMS current instead of average current that many electrical meters read. All electricians should understand the difference between reading circuit parameters with an average reading or true RMS reading meter. One can find a huge amount of literature on the internet dealing with the subject, and most new meters that an electrician purchases are of the true RMS type. However, each electrician should check to be certain of the type meter they are purchasing. With the harmonics, and distorted sine waves found in many facilities today, my belief is than an electrician should only carry a true RMS reading meter in their toolboxes. This includes voltmeters and amp meters. If an electrician asks you to help find why a 200-amp circuit breaker is getting hot and tripping, but the electrician only measures sixty amps with his ammeter, you will soon become a believer in true RMS reading meters. Many times in harmonic rich environments, an average reading meter will only read the connected amp load to the equipment, but in reality, the breaker is seeing the heating effects of harmonics or distorted waveforms. Electrical manufactures design circuit breakers to operate a 60 Hertz. The third, fifth, and ninth harmonics cause the breaker to heat, which in turn lowers it trip rating drastically.

The Underwriters laboratories (UL) and NEMA have classified all types of fuses into specific classes determined by their amperage, size, construction, and the type of fuse mounting uses. These classes are type G, H, J, K, R, and T for cartridge fuses.

Class G Fuses – The Class G fuse are for use in lighting and appliance panel boards and incorporate a fusible-switch unit. This class of fuse is current limiting and is available with a time-delay option.

Class H Fuses – The Class H fuse is a cartridge fuse suited for general-purpose branch circuit, lighting circuit, and the protection of non-inductive equipment like electric ovens and resistance heaters. Manufactures produce them in renewable or non-renewable types. The renewable types cannot be time-delay rated due to the replaceable link. This class of fuse is also available with DC ratings.

Class J Fuses – The Class J fuse is non-renewable and current limiting. These fuses have an interrupting rating of 200kA (kA = thousand amps). Time delay versions are available.

Class K Fuses – The Class K fuse is a non-renewable fuse that is subdivided into individual classes, defined as Class K-1, K-5, and K-9. They are available in 250 and 600-volt versions. The K-9 version is now obsolete. Class K-1 fuses provides the best degree of current limitation. The standards for Class K fuses allow a maximum peak let-through current and maximum I2t let-through energy for each class.

One must note that the Class K fuses are interchangeable with the Class H fuses, which is noncurrent limiting, so be very careful with replacements.

Class R Fuses – The Class R fuse is non-renewable and provided in 250 and 600-volt ratings. Class R fuses are separated into two classes, RK1 and RK5. RK1 is available with interrupting ratings of 300kA. Both RJ1 and RK5 are current limiting.

Class RK1 and RK5 are electrically the same as K-1 and K-5 fuses, however they are provided with ferrules and knife blades modified to conform to Class R rejection standards. The grove in the ring of the ferrule and the slot in the knife blade prevent the installation of other fuse classes into the holders designed for Class RK1 or RK5 fuses.

Class T Fuses – The Class T fuse is non-renewable and provided in 300 and 600 volts. They are current-limiting and designed for the protection of feeders and branch circuits in accordance with the NEC. They are available in a time delay version and available with DC ratings.

THE SINGLE ELEMENT FUSE

The basic component of a fuse is the link. Depending upon the ampere rating of the fuse, the single-element fuse may have one or more links. They are electrically connected to the end blades or ferrules and enclosed in a tube or cartridge surrounded by an arc quenching filler material.

Single element fuses are very fast acting to short circuit currents and work well to protect such equipment as electronic equipment, resistive heater elements, and load with no inductive surge current when power is applied.

DUAL ELEMENT FUSE

You can apply the dual element fuse to circuits subject to temporary motor overloads and surge currents to provide both high performance short circuit and overload protection. Over sizing in order to prevent nuisance openings is not necessary. You can and should size these fuses at 125% of the FLA. The links in the fuse are similar to those of the single element fuse and will provide fast short circuit clearing times, and allow for low level over current when a motor first starts.

SEMICONDUCTOR FUSES

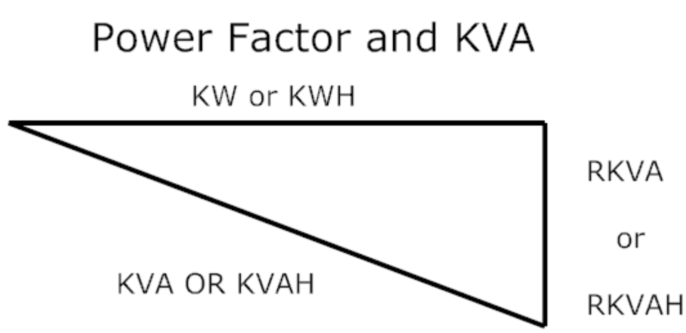
Power semiconductors used in solid-state power equipment such as rectifiers, inverters, and variable speed motor drives, require very fast limiting fuse protection. These devices can sustain heavy damage if short circuit currents are not cut off and limited by special fast acting fuses. Semiconductor fuses are often applied where DC interrupting capabilities are required. When one needs to protect very expensive electronic equipment, the investment in semiconductor fuses is highly recommended.

Chapter 18 - Utility Metering and Power Factor

The actual load on a utility system is KVA, not KW as many people think. KW is the resistive element of the power triangle. KVA is a function of power factor and KW, and includes the reactive portion of the power triangle. The word reactive takes in the inductance and capacitance imposed on the system. The inductance would be from such loads as motors and transformers. The capacitive element would be from power-factor correction capacitors.

The following formula applies:

Power factor = cosine of the angel = KW/KVA or KWH/VKAH. See Figure 1 for the power triangle.



The three sides of the reactive power triangle

Figure 1

You must remember that only KW, KWH, RKVA, OR RKVAH, can be measured. KVA or KVAH are mathematically calculated values.

KW = Kilowatts = 1000 watts
KWH = Kilowatt hours
RKVA = Reactive thousand volt amps
RKVAH = Reactive thousand-volt amp hours
KVA = Thousand volt amps
KVAH = Thousand-volt amp hours

Power factor is usually expressed as a percent. A cost penalty is the utilities rate structure will be imposed if the power factor is low, usually below 80 or 85%. It may be based on peak RKVA, RKVAH, or through calculation of power factor. For large electric users, penalty may start a 95% power factor or demand charges may be added, based on KVA. Demand and KW charges can get pricy if the buildings power factor is low.

Chapter 19 - MOSFET semiconductors

The word MOSFET stands for – metal-oxide field effect semiconductor

The power MOSFET used as a switch

The MOSFET was developed out of the need for a power device that could work beyond the 20-khz frequency spectrum, anywhere from 100 kHz to above 1 MHz, without experiencing the limitations of the bipolar power transistor.

The power MOSFET offers the designer a high-speed, high-power, high-voltage device with high gain, almost no storage time, no thermal runaway, and inhibited breakdown characteristics. Different manufactures use different techniques for constructing a power FET, and names like Hexfet, Vmos, Tmos, etc., have become trademarks of specific companies. The bottom line is that all MOSFET's work on the same principle.

BASIC MOSFET DEFINITIONS

Comparing the NPN bipolar transistor elements with the n-channel MOSFET shows that the:

Base = gate
Emitter = source
Collector = drain

Although both deices are called transistors, it is important to understand that there are distinct differences in the construction and principles of operation between bipolar and MOSFET devices. The first and most important difference is the fact that the MOSFET is a majority carrier semiconductor, while the bipolar is a minority carrier semiconductor.

The MOSFET operates in the depletion mode. They conduct heavily without bias voltage applied between the gate and source. The application of bias voltage then reduces the current through the drain-source circuit. The MOSFET can be produced so that it operates in the enhancement mode. In such operation, forward-bias voltage must be applied between the gate and source in order to produce current in the drain-source circuit. This, of course, is similar to the situation prevailing in ordinary bipolar transistors.

A significant difference is that the input circuit of the bipolar transistor consumes current, whereas the gate of the MOSFET makes no such demand from the input source. Input resistance of the MOSFET can be about 10 megohms.

GATE DRIVE CONSIDERATIONS OF THE MOSFET

Remember that the bipolar power transistor is essentially current-driven and a current must be injected at the base in order to produce a current flow in the collector. This current flow in turn is proportional to the gain of the bipolar transistor.

The MOSFET is a voltage-controlled device. A voltage within certain limits must be applied between gate and source in order to produce a current flow in the drain. Since the gate terminal of the MOSFET is electrically isolated from the source by a silicon oxide layer, only a small leakage current flows from the applied voltage source into the gate. Because of this fact, we can say that the

MOSFET has an extremely high gain, and high impedance.

In order to turn a MOSFET on, a gate-to-source voltage pulse is needed to deliver sufficient current to charge the input capacitor in the desired time.

To turn off the MOSFET, we need none of the elaborate reverse current generating circuits described for bipolar transistors. Since the MOSFET is a majority carrier semiconductor, it begins to turn off immediately upon removal of the gate-to-source voltage. Upon removal of the gate voltage, the transistor shuts down, presenting very high impedance between drain and source, thus inhibiting any current flow, except leakage currents. One must remember that the drain current starts to flow only when the drain-to-source avalanche voltage is exceeded, while the gate-to-source voltage is kept at 0 volts.

TESTING A POWER MOSFET

To identify the pins and the channel type, use these test procedures

The following measurements are taken with an analog Simpson 260 meter.

Gate to drain – infinite ohms both ways
Gate to source – infinite ohms both ways

Drain to source – N-channel
Continuity with negative on drain

Open with positive on source

Drain to source – P-channel
Continuity with positive on drain
Open with negative on drain

Chapter 20 - GFCI and AFCI Interrupters

GFCI DEFINITION– a GFCI is a ground fault circuit interrupter.
AFCI DEFINITION– an AFCI is an arc fault circuit interrupter.
DWELLING UNIT (NEC) DEFINITION – A single unit, providing complete and independent living facilities for one or more persons, including permanent provisions for living, sleeping, cooking, and sanitation.

GFCI REQUIRED LOCATIONS

Bathrooms
Garages and accessory buildings
All exterior receptacles except for equipment used for deicing
Crawl spaces, at or below ground level
Unfinished basements
Kitchens
Laundry, Utility, We Bar Sink Areas

Boathouses –If you have a receptacle located in your boathouse, a GFCI is required and very necessary.

GFCI INFORMATION

GFCI interrupters help protect people from severe or fatal electrical shocks. It provides this protection by detecting ground faults. The GFCI monitors the flow of electrical current and senses any difference between the current flowing in and the return current. Another words, it looks for a loss of electrical current.

The GFCI has a test button that produces an electrical difference in the current flow between the hot and neutral conductor. The button causes a current flow of around 8ma to flow. The setting on a GFCI is set to trip at 5ma, so the test current of 8ma forces the interrupter to trip.

AFCI REQUIRED LOCATIONS – Combination type

Family Rooms
Dining Rooms
Living Rooms
Parlors
Libraries
Dens

Bedrooms
Sun Rooms
Closets
Hallways

AFCI INFORMATION

AFCI interrupters help protect against electrical fires caused by arcing faults. The new generation of AFCI interrupters protects from parallel arcing faults, and protect from series arcing faults at lower fault levels. The parallel arcing fault might occur from line to neutral or line to ground faults. This might occur from a damaged lamp cord from a vacuum cleaner beater brush hitting it, or rolling a dresser across the cord. Then if the cord lies on a combustible surface such as a carpet floor and sparks, you then can have a fire. The cause for a series arcing fault might occur from events such as a loose screw on the lamp socket, or on the wall outlet itself. You must remember that if the first arc ignites a combustible substance, it is too late, and the tripping of the AFCI interrupter will not extinguish that fire, although removing the arcing source will not allow the advancement the already burning fire. That is one good reason to use common sense and handle cords with care, and to do proper housekeeping around these cords.

AFCI TROUBLESHOOTING TIPS

Some electricians have had trouble with AFCI breakers that trip when they turn on a light switch, or apply a load to an outlet. There have also been reports of electricians who have had trouble with bath fans tripping the AFCI breakers for no apparent reason. Some of these problems were the result of defective AFCI breakers, but the vast majority of them are the result of defective devices plugged into the receptacles, defective fans, or a problem with the wiring. Now before you get your hackles up, remember that I am one of those electricians that work with these devices in the field during a normal workday. I do not blame an electrician for wiring errors until I discover the true cause of the problem.

Here is a point to remember about AFCI breakers. First and most importantly is that the electronics inside an AFCI also detect ground fault currents just as a GFCI would do. Therefore, if you have any of the problems that we electricians find that will trip a GFCI, those problems will also apply to an AFCI breaker. Things like a staple or other fastener driven through the NM cable between the neutral and ground, a bare ground wire inside a device box that is touching on the neutral conductor. I have found that the use of a simple ohmmeter or a low voltage megger will usually reveal the true problem. If the wiring system will pass a megger test, then it will work with an AFCI breaker. Believe me when I tell you that a low voltage megger will pay for itself when dealing with AFCI and GFCI problems. Remember when you use the megger that you want to measure from neutral to ground on the wiring to identify staples and such. Remember to disconnect the wiring off the breaker or you will read a short from neutral to ground, since the neutral is at some point bonded to ground at the panel.

Here is my final point. If an electrician does not test his work with a megger before the wiring is covered, you are a fool. Better yet is to power all the circuits that will contain these devices before you all the contractor to cover your work. At least you will be certain your wiring was not defective before they installed the drywall. Back a few years ago, if a romex had a staple or drywall screw between neutral and ground, you probably would never discover the fault. Today with the use of GFCI and AFCI interrupters, these types of problems will rear their ugly heads often.

Chapter 21 - Meters and Harmonics—What You Need to Know

As a master electrician, I have spent many long hours working in industrial plants, working on direct current motor drives, inverters, and other electronic devices that produce harmonics on the building power supplies.

I wrote this article to help electricians select the proper test equipment required to service electrical equipment operating in harmonic rich environments.

I do not intend to give you an education in electronics and the complexities of thyristors, SCR’s, and switch mode power supplies, and instead I would like to help you select the proper test equipment to obtain accurate measurements while working on electrical systems influenced by the harmonics these devices produce.

First, let me give you some background about the meters we electricians and electronics technicians use on a daily basis. Most all of us carry some form of a voltmeter, ohmmeter, and clamp-on ammeter in their toolboxes or pouches. Many of these meters are inexpensive models, and designed for reading the voltage or current found in 60 Hz power systems. These meters, called average response meters, work well in 60 Hz electrical systems where the loads produce no harmonics. Now you need to understand that a harmonic is some multiple of the 60 Hz fundamental frequency. A third harmonic would be three times 60 or 120 HZ. Did you just catch the concept? The average reading meter, designed for measuring 60 Hz power, will no longer be accurate when harmonics are present.

Let me give you a real-life example. The plant manager called me to his industrial plant to help the staff maintenance electrician find the reason why a 600-amp I-line breaker was tripping for no apparent reason. The electrician had discovered that the breaker would run very hot after a few minutes, then finally trip out and shut down a portion of the plant. The electrician had measured the amperage passing through the breaker to the load at 175 amps on all three phases. The electrician determined the breaker was defective and ordered a new one. You probably already guessed that the new breaker also tripped, or they would not have requested my assistance. When I arrived, the breaker was very hot and the electrician said the breaker would probably trip in a matter of minutes. The breaker tripped about three minutes later. Instead of letting the breaker cool off, I replaced the breaker with the original one that was cold, and turned the power back on. When I put my Fluke, true RMS reading meter on the phases, the current draw from the load was reading 634 amps.

The electrician laughed at me. The snot nosed kid laughed at my meter readings. He pulled out his hand dandy clamp on meter and placed it on the same phase lead as my meter and his meter read around 180 amps. Then it was my turn to laugh. I said to him, “If the load is only drawing 180 amps, why does the breaker overheat and trip out? The snot nosed brat had no answer so I proceeded to school him. I looked at the panel schedule to determine what loads the breaker was feeding. The electrician took me to the sub-panel where we found the source of the overheating breaker. The company had recently installed a new machine with direct current motor speed control drives on it. An isolation transformer fed the two 100 hp motor drives. The manufacturer had supplied the transformer to prevent harmonics created by the drives from traveling onto the plants power system. It took little time to discover that the secondary of the transformer was an ungrounded delta connection. I bonded the H1 lead of the delta windings to ground. They call this arrangement a corner grounded delta system, and, no, the breakers will not trip, unless of course a second ground occurs on the transformer secondary. The purpose of grounding the secondary is to prevent the objectionable harmonics from the drive from traveling from the transformers secondary to it primary and out onto the plants power system.

When we reapplied power to the equipment, my true RMS reading meter read within a couple of amps of the snot nosed kids ammeter. I watched him write down the name and model number from my Fluke meter and put the note into his wallet. I suspect his boss began a payroll deduct plan for the new meter his electrician purchased later that day. The point of all this discussion was not to show how smart I am, but instead to show you that using the correct meters and understanding why you are using a certain meter is essential when working on any equipment that is in a harmonic rich environment.

Let’s discuss another source of harmonics, this time we will move our toolboxes into your home. Will we find any electrical equipment lurking around your house that might cause unwanted harmonics? You bet we will. If you are reading this article on your computer, you just discovered a big source of harmonics. The source of those harmonics is the (switch mode) power supply that produces the 5 VDC, 12 VDC power needed by the computer. These switch mode power supplies convert the 120-VAC to direct current by switching the power on and off at high frequency (rectification), then filtering it with capacitors and filtering networks. As the semiconductors rapidly switch the power on and off, the switching produces harmonic frequencies, multiples of the 60Hz power supplying the power supply. Another source of harmonics in the home is from fluorescent lights with electronic ballasts. These ballasts produce the high voltage required to light the lamps with electronic circuits. The ballasts can produce very efficient use of the current that the lamps consume, but they operate at a high frequency. Some of these ballasts can cause harmonics to appear on the power lines, especially in large quantities.

So now you may ask yourself the question, what good is my average reading meter in today’s workplace? The answer to the question comes by taking just a moment and considering what you are attempting to accomplish with your measurements. If you simply want to know if a newly wired motor is drawing the correct amperage shown on the nameplate, then most average reading meters will do the job quite nicely. If however, you are troubleshooting the reason for breaker trips or equipment failures, then the use of True-RMS reading meters is essential.

I am a believer that every electrician working in any environment other than residential should purchase a true-RMS reading meter. Most clamp-on meters manufactured today offer not only the clamp on ammeter, but also AC and DC voltage, along with ohmmeter and continuity testers all in one. It is important when working on today’s electrical systems that we are able to accurately measure the true amperage that an electrical component experiences. Harmonics produce a false load on electrical devices, and on electrical system neutral conductors. Being able to ensure that a device or the neutral conductor is not overloaded, will save you, the owner, and the fire department, many hours of frustration.

Take the time to read the owner’s manual of your test equipment and do a little research. You do not need to be an electrical engineer to work with today’s electrical and electronic systems, but you do need a lot of common sense, and a well-rounded understanding of how harmonics influence the electrical systems you work with every day. If you would like to dig a little deeper into harmonics and proper meter use, click on the following links. The websites will give you a wealth of good information to help you.

http://www.electrical-contractor.net/Need_To_Know/Harmonics.htm

http://support.fluke.com/find-sales/download/asset/1260729_d_w.pdf

http://www.myflukestore.com/crm_uploads/fluke_clamp_meters_-_proper_use_of_clamp_meters_in_commercial_and_residential_settings_application_note.pdf

Work safe my friends, and wear your insulating gloves and safety gear when clamping or probing on live electrical conductors.

Chapter 22 - Direct Current Motor Notes

As most electricians work with direct current motors, they discover that dealing with the many ailments these motors suffer is endless. Such things as worn brushes and commutators, misaligned brush holders; and worst of all, incorrectly connected tachometers that cause a motor drive fault, or allow the motor to run away to dangerous speeds, may seem overwhelming. The intent of this article is to pass on some of the information I have gained over the years as I troubleshot and performed preventive maintenance on the motors.

Many of the D.C. motors I work with are of the compound type, meaning they have both series and shunt wound fields. These motors work well for the larger horsepower sizes because they provide excellent starting torque, and good constant speed. You can control the speed with a rheostat in the shunt field, although that method is seldom used.

When wiring these compound motors, it is imperative that the electrical polarity of the shunt field exactly match the series field voltage or motor instability may develop under certain loading conditions. The following chart will assist you in wiring the motors to obtain the rotation direction you require for your installation and still maintain the correct polarity between the two field windings.

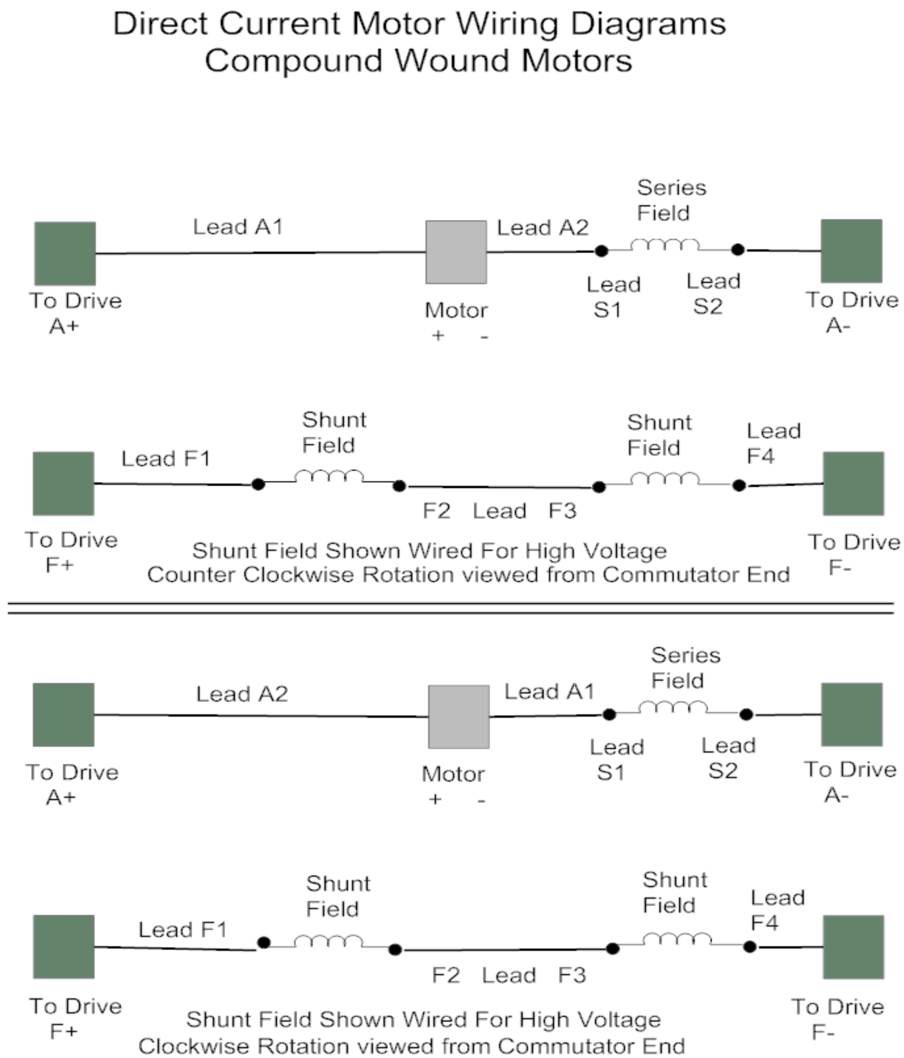


Figure 24A

Many times, I have had to work with motors that use European terminal designations. I have had to wire the motors to direct current drives with American terminal designations. Here is a simple chart to help you convert those designations.

European	American
Terminal Z	Armature A1
Terminal V	Armature A2
Terminal U	Field Winding F1
Terminal X	Field Winding F2
Terminal Y	Protector P1
Terminal W	Protector P2

Note: The protector terminals are an internal winding temperature thermal. The protector opens if the windings become overheated.

Belt Tension and Motor Bearing Life

V-Belt tension between a motor pulley (sheave) and the load pulley is very important to prolong the motor bearing life cycle. There are a multitude of formula's and instruments to determine how tight the belts should be. I have found that the following method works in most cases for determining the proper tension. If you have had problems with premature bearing failures, I suggest that you contact the motor service center or the manufacturer. They often times can assist you in correcting the problems. Remember that factors such as the diameter of the sheaves can determine the load factor on the motor bearings; misalignment, high load starting stress, and temperature all effect the life of the motor bearings.

Here is how I determine v-belt tension. The rule says you should have no less than 1/64-inch per inch of span. If you measure the span from the center of the motor shaft to the center of the load shaft in inches, and then multiply that value by .016 inch, you will arrive at the total deflection of the belt in inches.

If you prefer to do the calculations in metric format, multiply the span in meters, by 16.

Power Supply Identification

Some form of rectified power supply will power many of the DC motors that we as electricians deal with. Many, if not most of these motors have a stamped letter on the motor nameplate that gives the user some idea as to the type of rectified power supply they were designed to operate with. Here is a list of those letters and their meaning.

Identification Letter "C"

This designates a three-phase, 60 hertz input, and full-wave power supply having six pulses per cycle. Electronic control of the six pulses provides for motor speed control.

Identification Letter "D"

This designates a three-phase, 60 hertz input, bridge type power supply having three controlled pulses per cycle.

Identification Letter "E"

This designates a three-phase, half-wave power supply having three total pulses per cycle and three controlled pulses per cycle.

Identification Letter "K"

This designates a single-phase, full-wave power supply having to controlled pulses per cycle, and usable on to hertz inputs.

Brushes and commutator Inspection

Good brush performance is dependent on a number or variables. Proper fit and adjustment at the time of the brush replacement is essential. Be very careful not to use silicone products around motors that utilize brushes. The silicone vapors may cause rapid degradation of the brushes and in turn, damage to the commutator may result. Make it a practice to use gasket material instead of caulks and sealants if you need to seal surfaces such as ventilation ductwork.

Many of the brushes used today have crimp marks in the copper leads. When the crimp marks enter the brush holder, it is time to inspect the brushes and commutator. If you discover that your motor has rapid brush and commutator wear, contact your motor service center or the manufacture to investigate replacing the brushes with a different brush material. Only someone well versed in motors should make any changes to the brush material. Severe commutator damage could result.

Proper Replacement Brush Fit

Replacement brushes should have the surfaces that touch the commutator sanded to match the curves surface of the commutator. Use a coarse non-metallic sandpaper to accomplish this. Place the sandpaper with the coarse side up towards the brushes and move the paper back and forth until the brush closely matches the commutator surface. DO NOT US EMERY CLOTH. Be careful to vacuum the excess carbon dust out of the motor and windings, as it is very conductive.

Motor Insulation Resistance

As the one responsible for the preventive maintenance of the large horsepower motors in one industrial plant, I began using insulation testing to help in the determination of when a motor needed to be removed and sent out to the motor shop for maintenance. There are a number of considerations to take into account when attempting to determine the time between motor overhauls. Bearing life, brush and commutator wear, along with environments influences such as excessive heat and contaminants are all part of the equation. I also added armature and field winding insulation resistance into the equation.

I found that if I measured the windings insulation resistance at the time we installed the motor after an overhaul; I could locate motors where the insulation of the windings had degraded. Often times a tiny crack in the insulation allowed moisture and contaminates to invade the windings, which would lover the insulation resistance. I have all kinds of charts to determine the acceptable insulation values, but starting with a freshly overhauled or new motor gives one a starting reference point to begin the evaluation. The lowest acceptable value I decided upon was 1.5 megohms before I pulled the motor from service. I took the readings for one minute and converted them to 104 degrees Fahrenheit.

I hope this information will assist you the next time you need to work on direct current motors.

Chapter 23 - Electrical Panel Cooling Requirements

As electricians, we are often required to deal with overheated electrical panels. Very few industrial plant production areas are air-conditioned well to keep the electrical and electronic panel temperatures within a specified range. Many times, you can simply put cooling fans and filters, or heat pipes that run off compressed air on the panels to ventilate them. Heat pipes are notorious for contaminating the panel interior with oil vapor no matter how much filtering one does. Therefore, many electricians install some form of air conditioning system to cool the panels that contain delicate electronics such as inverters, drives, power supplies, and other forms of semiconductor devices.

Solid-state equipment has a temperature limit: Above that point, it will suddenly cease to function or catastrophically fail. Heat pipes and cooling fans can lower the temperature in a cabinet, but only to the ambient temperature surrounding the panel. To lower the heat and humidity to acceptable levels, some form of air conditioning will be required. There are two sources for the heat inside the panel. The first is the heat conducted through the metal cabinet walls, the other is the heat dissipated by the internal electronic/electrical components inside the cabinet.

You can determine the BTU/HR requirements for lowering the internal cabinet temperature to a given level by the following method.

Find out how far below the ambient temperature the internal temperature should be. If the highest room ambient temperature never exceeds 100 degrees Fahrenheit, and we would like to lower the temperature to 85 degrees, then we would need to lower the temperature by 15 degrees internally.

Find the outside square foot area of the entire cabinet (six sides). From the chart below, for 15 degrees below ambient, multiply the 10.2 BTU/SQ. FT, times the square foot area of the cabinet. This will be the BTU/HR required for the cabinet only.

TEMPERATURE DIFFERENTIAL	CONVERSION CHART
Temperature Degrees Fahrenheit	BTU per square foot
10	5.8
15	10.2
20	14.6
25	18.7
30	22.8
35	27.2

Determine the internal equipment alternating current input power load in watts by using the product of the line voltage and amperage. If there is an external load supplied from within the cabinet, subtract this load from the input power calculations. Only watts used within the cabinet is important. These watts x 3.414 = BTU/HR required for the internal load.

Add together the BTU/HR for the cabinet and BTU/HR for the internal equipment. If the number should come out to a value such as 5377 BTU/HR, then use the next larger size air conditioner, such as 6000 BTU/HR.

Chapter 24 - Wiring, Installation, and Thermocouple Applications

Because thermocouples are differential transducers, they have their own rules and codes, which one should follow to ensure sound, repeatable results. Here are some of the more important rules that will assist you in applying thermocouples in your next installation. I have included a link to a major supplier of thermocouples and accessories. They have provided me with products and technical assistance for many years, and I suspect you will also find them very helpful.

http://www.omega.com/toc_asp/sectionSC.asp?section=A&book=temperature

Thermocouple wire must be used from the hot junction leads back to the point of reference; e.g. at the computer interface card, recorder, digital indicator or temperature controller.

Be consistent with the thermocouple type from start to finish. If the system calls for type K thermocouples, then the probe, connectors, extension leads, and indicator must all be for type K calibration.

Switches may be used if they are manufactured with silver or gold-plated contacts, provided that:

The design of the switch is of the isothermal type.

Use thermocouple wire from the common output to the reference junction.

Avoid splitting the output of a thermocouple between two readout devices such as a recorder and a controller. This arrangement may work, but usually there are impedance matching problems or possible generation of unwanted ground paths. A better choice would be to use dual ungrounded thermocouples.

You should route thermocouple wires away from large current carrying or voltage wires. If run in a conduit, you should run it with signal carriers only.

Thermocouple wire may be limited in use by temperature constraints on the insulation and by wire diameter.

Feedthroughs that are not of thermocouple material are a source of error if a temperature gradient exists through the wall.

Install immersion type thermocouples to a depth of ten to twenty times the sheath outer diameter to reduce conduction losses.

The negative lead of a thermocouple is always color-coded red per ANSI standards.

Do not use thermocouples in microwave or radio frequency heated ovens. Take measurements only with the heat source off.

Grounded and ungrounded probe configurations refer to the relationship between the sheath and thermocouple junction. When they manufacture an ungrounded probe, the junction is electrically isolated from the metal sheath, which may be a source of outside noise or unwanted voltages. In a grounded probe, they ground the junction directly to the metal sheath. Grounded junction probes have better response times than ungrounded probes.

Be aware of a hysteresis effect in type-K thermocouples used at high temperatures above 1000 degrees Fahrenheit.

When using type-K thermocouples, green rot can become a factor in temperature errors in oxygen-deprived atmospheres.

Avoid direct flame measurement with bare wire thermocouples.

Notes:

Type J thermocouples—iron (positive) white wire.

Constantan (negative) red wire

Outer jacket colors—thermocouple grade wire is brown; extension grade wire is black.

White positive lead will attract a magnet.

Type K thermocouples—cromel (positive) yellow lead

Alumel (negative) red wire

Outer jacket colors—thermocouple grade wire is brown; extension grade wire is yellow.

Red (negative) lead will attract a magnet

Chapter 25 – Calculating Timing Belt Sizes

As electricians, we often have to deal with cogged motor drive or timing belts. When dealing with those cogged belts, it is often difficult to determine the size of a replacement belt when the numbers of the belt have worn off. The belt has teeth molded directly into its surface, which mesh with the corresponding teeth in a pulley or multiple pulleys. The design of cogged belts helps to prevent slipping under load. They are often called timing belts.

Here is an easy method to determine the length and width of these belts before you call your supplier for a replacement.

Count the teeth on the belt

Measure the pitch (center to center of the teeth) in millimeters.

Multiply the number of teeth by the pitch.

To get the length of the belt in inches, divide the length in millimeters (MM) by 25.4.

If you counted the teeth correctly, you will come out with even inches and no fractions. If you come up with a fraction, you have miscounted teeth by one in either direction.

Here is an example:

381 teeth and 8MM pitch

381 x 8 = 3048

3048/25.4 = 120 inches

Measure the belt width in millimeters.

You now have enough information to locate a replacement belt for your machine.

I have provided a link to the Gates Power Transmission website if you should need more information or assistance. http://www.gates.com/index.cfm?location_id=534

Chapter 26 - Oscilloscope Instructions

As electricians, we are often required to troubleshoot direct current motor speed control drives. This article explains a typical oscilloscope setup that will give you a starting point.

TEKTRONICS 2213A SCOPE SETUP FOR D.C. DRIVE WORK

1. Install an X100 probe on channel 1 and one on channel 2. The use of two probes instead of using the scope ground, insures that a ground is not placed on the drives output. Any ground on the armature or field motor leads will cause an immediate ground fault and will damage the drive semiconductors and/or electronics.
2. Install the line cord in the back of the scope and apply 120 VAC power.
3. Press in the power on-off button, and wait about ten seconds for the power on light to light.
4. Preset the front panel controls as follows;

[DISPLAY]
Intensity ----mid position of the potentiometer
Focus---------mid position (adjust for sharpness

[VERTICAL CHANNELS (BOTH USED)]
Position---------------mid position
Vertical mode----------Both
BW limit---------------Off (button out)
Volt/div. --------------2 (under 1X)
Volt/div.--variable----Cal (detent)
Channel 2 input--------On (button in)
Input coupling---------DC

[HORIZONTAL]
Position---------------Mid position
Horizontal mode--------No delay
Sec/div. ---------------2 ms
Sec/div.-variable------Cal (detent)
X10 multiplier---------Off (knob in)
Range selector---------0.4 ms
Multiplier-------------<X1

[TRIGGER]
Var. hold off------------Norm
Mode-------------------P-P auto
Slope------------------Out
Level------------------Midrange
Int. -------------------Vert. mode
Source ----------------Int.
Ext coupling-----------AC

5. Adjust the intensity control for the desired display brightness.
6. Adjust the vertical and horizontal position controls as needed to center the trace.
7. Connect channel 1 probe on the drive A1 lead and channel 2 probes on the drive A2 lead.
8. Do not ground the scope to any part of the drive electrical system.
9. The only ground required is the factory installed power cord ground to protect the operator! Please contact a qualified service company if you have any doubt about the proper use of measuring and testing equipment with motors and drives. You could damage the electrical

equipment or worse yet, injure or kill you or others working around you. Use extreme caution when working around motor drives.

Chapter 27 - Semiconductor Prefixes and Suffixes

Registered Types

In the United States, the Joint Electron Device Engineering Council (JEDEC) of the Electronic Industries Association (EIA) assigns a type designation number upon request from a manufacturer, and then publishes the manufacture's specification for that type. The specifications become public property, and any manufacturer may produce the device, but must meet strict requirements if branded with the JEDEC designation.

The European equivalent of JEDEC is Pro Electron. The Japanese equivalent, Japanese Industrial Standards, commonly called the Japanese JEDEC in the United States.

Prefixes for Registered Types

USA - JEDEC
- 1N – Diode or rectifier (Device with one P-N junction)
- 2N – Transistor or thyristors (two junctions)
- 3N – FET (Field Effect Transistor) (three P-N junctions)

PRO ELECTRON
- A – Germanium Product
- B – Silicon Product

Subsequent letter designations for high or low power, high or low frequency devices

JAPANESE JEDEC
- 1SS – Signal diode
- 1SV – Varactor (variable capacitance) diode
- 2SA – PNP transistor, high frequency

2SB – PNP transistor, low frequency
2SC – NPN transistor, high frequency
2SD – NPN transistor, low frequency
2SJ – JFET, P-channel (Junction field effect transistor)
2SK – MOS/FET (Metal oxide semiconductor field effect transistor)

Generic Part Number Prefix Code

AD Analog – digital
AH Analog hybrid
AM Analog Monolithic
CD CMOS digital
DA Digital – Analog
DM Digital monolithic
LF Linear FET

LH Linear hybrid
LM Linear Monolithic
MM MOS monolithic
TBA Linear monolithic

Note: Remember that the "2S" in a Japanese type number might not appear in the part number. A transistor marked D945 is actually a 2SD945. The third digit represents the type as shown above. Example:

A = PNP high frequency
B = PNP low frequency
C = NPN high frequency
D = NPN low frequency

I often find that the identification of semiconductor devices to be the most difficult part of servicing electronic equipment. I hope this article helps you the next time you struggle to identify a component.

Chapter 28 - NEMA Enclosures

As electricians, we all have had to deal with the sizing and purchase of electrical equipment enclosures. Selecting the correct size is something only you can determine. However, I can help you select the correct NEMA rated enclosure for the environment your equipment will be required to withstand. Remember that these enclosures are for non-hazardous environments only. I will list the types generally used by electricians. There are other types, but they seldom find use on the jobsite.

TYPE 1—these enclosures are intended primarily for use for housing electrical equipment that is undercover or indoors. They are best suited for the protection of personnel from dangerous electrical shock, but also provide some protection from falling objects or debris.

TYPE 3R—these enclosures find use for indoor and outdoor protection to people against access to electrical hazards, and provides protection against egress of water, rain, sleet, and snow. It also provides protection for the contents from physical damage due to falling and flying solid objects. Electricians use this enclosure extensively to protect equipment installed outdoors from the elements. Be certain that you do not drill holes in the top of the enclosure. If you must enter a conduit from the top, use a hub to provide a watertight connection. If you enter conduits on the sides, use sealing washers to ensure that liquids cannot enter around the conduits.

TYPE 4X—these enclosures provide the same protection as NEMA 3R enclosures, but they are constructed of stainless steel, aluminum, or fiberglass. This classification provides a degree of corrosion protection required for some industrial plants and around certain processes.

TYPE 12—these enclosures are constructed without knockouts. They are for indoor use to provide protection to personnel against hazardous electrical voltages, and provide protection for the contents of the enclosure. They provide some protection from falling dirt, circulating dust, lint, fibers, and flying particles. This classification also provides some protection to the ingress of water, dripping and light splashing.

International Standards IP Protection Classification

The IEC specifications are showing up more and more in the American electrical industry. To use the specification, you must inspect both of the numbers following the IP letters. The first number provides us with the protection against solid objects, such as fingers. The second number provides us with the protection level against liquids. The standard does not provide us with guidelines for the risks of explosion, corrosion, icing, oil and coolants. Therefore, the IP standards do not exactly match those of NEMA enclosures.

FIRST NUMERAL	TEST	SECOND NUMERAL	TEST
0	No Protection	0	No Protection
1	Protection against Solid objects up to 50 mm	1	Protection against Vertical falling objects
2	Protection against solid Objects up to 12 mm	2	Protection against direct Sprays of water up to 15 Degrees from vertical
3	Protection against solid Objects over 2.5 mm	3	Protection against sprays to 60 degrees from vertical
4	Protection against solid Objects over 1 mm	4	Protection against sprays From all directions
5	Protection against dust	5	Protection against low Pressure jets of water from all directions
6	Totally protected against dust	6	Protection against strong Jets of water
7	Totally protected against dust	7	Protected against the effects of immersion between 15 cm and 1 meter

Cross-Reference between NEMA and IEC enclosure types

Type	IP23	IP30	IP32	IP55	IP64	IP65	IP66	IP67
1	*							
2		*						
3					*			
3R			*					
3S					*			
4							*	
4X							*	
6								*

12				*		*		
13						*		

Chapter 29 – Controlling Power Factor

Repeatedly, electric motor users question the relative importance of power factor, efficiency and amperage related to operating cost. Perhaps the greatest confusion arises because early in science classes, instructors said that the formula for watts is amps multiplied by volts. However, this formula is true only for dc circuits and some ac loads, such as incandescent light bulbs and quartz heaters.

The formula changes when the loads involve a characteristic called inductance. We must alter the formula to include the term power factor. Therefore, watts equal amps X volts X power factor.

Power factor is always involved in ac power applications where inductive magnetic elements (solenoid coils, motor windings, fluorescent lamp ballasts) exist in the circuit.

Electrical flow into one of these devices has two components. One part, real power, is absorbed and utilized to do useful work. We borrow the second part from the power company and used to magnetize the magnetic portion of the circuit. Because of the reversing nature of ac power, we subsequently return this borrowed power to the power system when the ac cycle reverses.

Power factor, then, becomes a measurement of the real power, both borrowed and used. Power factor values will range from zero to1.

If borrow and return all of the power, without actually using any, the power factor would be zero. On the other hand, if all of the power drawn from the utility is used and none is returned (as in incandescent bulbs), the power factor becomes 1 or 100%.

In the case of electric motors, the power factor is variable and changes with applied loads. A motor running on a work bench with no load applied to the shaft will have a lower power factor (perhaps .1 or 10%), while a motor running at full load connected to a pump or fan might have a high-power factor (perhaps .88 or 88%). Between the no load point and the full load point, the power factor increases with the horsepower loading that is applied to the motor.

Efficiency, the measure of how well the electrical device converts power into useful work, is one of the most critical elements involved in motor operating costs. In motors, we do not convert all of the purchased energy into usable energy. Energy may escape through copper losses, and iron losses and the so-called friction and windage losses associated with spinning the rotor and bearings, and moving cooling air through the motor.

In an energy efficient motor, improved designs using high quality materials reduce such losses. For example, on a 10 hp motor, an energy efficient design might have a full load efficiency of 87%, meaning it converts 87% of the energy it receives into useful work.

We must consider the flow of electricity, amperes, into the motor. This flow includes both the borrowed and the used power. At low load, the borrowed power is a high percentage of the total power. As the load increases, the borrowed power becomes less of a factor. Thus, there is an increase in the power factor as the load increases. In a single-phase electrical motor, the actual power is the sum of several components:

A. The work performed by the system, such as, lifting with a crane, moving air with a fan, or moving material on a conveyor
B. Heat developed by the power lost in the motor winding resistance.
C. Heat developed in the iron through eddy current and hysteresis losses.
D. Frictional losses that occur in the motor bearings.
E. Air friction losses in the turning of the motor rotor, more commonly known as windage losses.

We express all of the above in watts or kilowatts, and we can measure them with a wattmeter. We can measure the apparent power, the product of the current multiplied by the voltage, with an ammeter and voltmeter. We now observe that in the case of the single-phase motor the apparent power thus obtained is greater than the actual power. The reason for this is the power factor.

This power factor reflects the differences, which exist between loads. A soldering iron is a pure resistive load, which converts the current that is absorbed directly into heat. We call the current, actual current because it directly contributes to the production of actual power. On the other hand, the single-phase electric motor represents a partially inductive load, which consists of actual current, which is going to be converted into actual power, and a magnetizing current that will generate the magnetic field required for the operation of the electrical motor. This magnetizing current corresponds to an exchange of energy between the generator and the motor. However, it is never converted into actual power. We call this current the reactive current.

EQUIPMENT CREATING POOR POWER FACTOR

It is practical to have an idea of the value of the power factor of commonly used electrical equipment. This will give an idea as to the amount of reactive energy that the network will have to carry.

LIGHTING

Incandescent lamps have a power factor equal to unity. Fluorescent lamps, usually have a low power factor, for example, 50% power factor is normal. These are often times supplied with a compensation device to correct the low power factor. With mercury vapor lamps, the power factor of the lamp is low, it can vary between 40% and 60%, but the lamps most often come with correction devices.

DISTRIBUTION TRANSFORMER

The power factor varies considerably in function of the load and the design of the transformer. A completely unloaded transformer would be very inductive and have a very low power factor.

ELECTRICAL MOTORS

Induction motors, the power factor varies in accordance with the load. Unloaded or lightly loaded motors exhibit a low power factor. The variation can be 30% to 90%.

INDUSTRIAL HEATING

With resistances, as in ovens or dryers, the power factor is often close to 100%.

WELDING

Electrical arc welders generally have a low power factor, around 60%.

HOW TO IMPROVE THE POWER FACTOR

We can improve power factor in two ways:

1. Reduce the amount of reactive energy.
   A. Eliminate unloaded motor and transformers.
   B. Avoid supplying equipment with voltages in excess of the rated voltage.
2. Compensate artificially for the consumption of reactive energy with power factor capacitors.

PURPOSE OF CAPACITORS

As previously shown, the power used by the industrial plants has two components:

1. Real power that produces work.
2. Reactive power needed to generate magnetic fields required for operation of inductive electrical equipment. This power produces no useful work.

The capacitor then performs the function of an energy storage device. Rather than transfer reactive energy back and forth between load and generator, the reactive energy to supply the magnetizing current is now stored in a capacitor at the load, thus reducing the distribution requirements for the excessive current. Thus, we have effectively reduced the total current requirement to the value of the useful current only, thus either reducing power cost or permitting the use of more electrical equipment on the same circuit. We must be careful to prevent an excessive amount of power factor correction with capacitors. Too much capacity on the line (leading power factor) is as bad, if not worse, than lagging power factor. Under certain conditions, dangerously high transient voltages may prevail on the power lines at points far removed from the actual load. In addition, we can transmit torque surges of over 20 times motor rating to the motor shaft under rapid restart conditions.

Ronnie Coleinger