IMPORTANT INFORMATION ABOUT THE NATIONAL ELECTRICAL CODE®

PETERSON ELECTRO-MUSICAL PRODUCTS, INC.

11601 S. MAYFIELD AVENUE ■ ALSIP IL 60803-2476

PHONE 1.708.388.3311 ■ FAX 1.708.388.3367

IMPORTANT INFORMATION ABOUT THE NATIONAL ELECTRICAL CODE®

The revised NATIONAL ELECTRICAL CODE® of 1990 includes substantial changes to the section pertaining to Pipe Organs. Before this revision, the Pipe Organ section had not been updated since the mid 1930s. Without reference to electronic circuits or modern types of power supplies and plastic insulated wire, this long outdated article gave little or no useful guidance towards establishment of safe, reasonable local codes. This resulted in various local inspectors demanding that Pipe Organs meet requirements that were often impractical and unnecessary. In 1988, a committee representing APOBA and AIO, including Richard Peterson, presented recommendations to National Fire Protection Association (NFPA, the publishers of NEC®) officials for revisions to the code that would spell out safe building practices without being unduly burdensome. The cooperative work that followed eventually lead to Article 650 of the 1990 NATIONAL ELECTRICAL CODE®.

We encourage you to become familiar with the NEC®. Getting into the habit of building organs that meet this code will make compliance with various local codes easier. Most local building codes are closely patterned after the NEC®, and many municipalities have adopted the NEC® in it's entirety. Although pre-existing installations are rarely required to be updated to meet new code specifications, any additions or modifications to organs, as well as new instruments, usually must comply. Even without considering local requirements, the specifications of the Code just make good sense! ***Please note that the information provided herein is based on our interpretation of the Code, as it applies to the use of Peterson equipment. Our guidelines may not apply when equipment manufactured by other companies is used. We believe our interpretation to be generally consistent with the interpretation of others in the Pipe Organ industry. Because interpretations may vary, we do not in any way guarantee that following our guidelines will make any part of an organ installation acceptable to any particular inspector. A copy of Article 650 of the Code is contained herein for your reference. Additional NEC® articles that relate to the use of electrical equipment in various types of buildings must also be considered. Using Peterson equipment in compliance with all codes is the sole responsibility of the installer.***

All Peterson Pipe Organ control systems manufactured today are built with NEC® requirements in mind. All wiring used within switching systems and for console cables, main cables, and chest cables meets applicable conductor size, covering, and "bundling" provisions. The magnet wire that we use for much of our cabling is acceptable to the NFPA and is generally recognized as having excellent fire safety characteristics. Many Transistor Driver, I.C. Driver, and DeMultiplexer/Driver circuit boards have fuses which limit current to 6 amps or less. Depending on the date of manufacture of your equipment, you may find fuses built into many other circuit boards for your convenience. In most cases when Peterson equipment is used as a complete package, no further fusing is required in these already-fused circuits. Our suggestions as to where fuses should be installed are detailed in the drawing on Page 9. Appropriate fuses and fuse holders are available from Peterson and in many cases are automatically included with switching and combination action equipment. For various cabling supplies and extra fuse blocks and fuses, please refer to our "Miscellaneous Parts" catalog.

The Code specifies minimum wire sizes for certain parts of circuits, but it is often advisable to use larger wires, especially in the case of long runs, so that the voltage drop along the wire's length is minimized. A useful "rule of thumb" to keep in mind is that as wire size increases by three numbers, such as from #15 to #12 AWG, the ability to carry current, at the same voltage drop per length, approximately doubles. A guide to wire size selection is included later in this booklet.

When using a complete system of Peterson equipment, our recommendations for sensible wiring and fusing consistent with our interpretation of the NEC® are as follows:

1) **Commons for key contact rails in manual and pedal keyboards:** When the key contacts are wired to a Peterson Diode Matrix ("Conventional") switching system, or to an Orga-Plex™ system with a DC Key Encoder (A separate wire will be run from each key contact to a keying input pin in this case), use one 6 amp fuse in the common wire from the rectifier to all keyswitch common "busses". A #18 AWG wire may be used for the connection from the rectifier main to the keyswitch common busses. Orga-Plex™ switching systems without DC Key Encoders use special cabling whereby one wire from each octave, plus one wire from all "C" keys, one from all "C#" keys, etc. are connected to the corresponding division encoding board. The voltage that feeds the keyswitch contacts in this case originates from the Orga-Plex™ power supply. Here, no additional fusing of the keyboards is required because internal current limiting is provided.

2) **Commons for Stop Action Magnet (Tablet or Drawknob) Switch Contacts:** A six amp or lower current rated fuse should be used in the switch contact common. A single conductor for this common should be at least #18 AWG. Individual #28 wires may be used to feed each contact separately, after the fuse. All combination actions manufactured recently and supplied cabled and mounted by Peterson for use with exclusively Peterson equipment, include fusing consistent with our interpretation of NEC®. NOTE -If relay coils are connected to a Peterson or other brand electronic combination action, or to reed switch contacts on drawknobs or tablets, then flyback spike protection and heavier current demand must be taken into consideration. Please contact the factory for assistance in this case.

3) **Chest common conductors:** Where Driver boards (such as Pipe Drivers and Straight Drivers) are not already fused at 6 amps or less, separate common conductors should be used for groups of chest magnets so that if all chest magnets are energized, no common wire will carry more than 6 amps. Each of these commons should be fused at 6 amps before connecting to a #14 AWG or larger main common return conductor. A conductor size of #18 AWG is suitable for carrying 6 Amps unless the run is long, as explained on Page 4 in this text. Note: Some people may consider the common conductor for each **group** of chest magnets a "**main** common return conductor in the electromagnetic supply", in which case it must be #14 AWG or larger. Use the method explained below to determine the approximate current draw for each chest magnet in order to determine how many magnets may be included in each "group". You may wish to make a judgement that **all** notes would never be played simultaneously and conserve fuses by making groups larger.

4) **Stop Action Magnet (drawknob or tablet) "On" and "Off" coil commons:** Because of the short duration of coil energization, and because only one coil per Stop Action Magnet is normally energized at a time, a single coil common conductor, fused at 6 amps, may be used for every ten Stop Action Magnets, assuming 28 Ohm or higher resistance coils. A single common conductor for ten Stop Action Magnets should be #18 AWG or larger to properly carry 6 Amps. Note: Some people might consider such a conductor a "**main** common return conductor in the electromagnetic supply", in which case it must be #14 AWG or larger. Individual common wires for each Stop Action Magnet may be as small as #26 AWG. Combination actions built recently and supplied cabled and mounted by Peterson, contain fusing arranged in a way that we believe is appropriate for NEC® compatibility in systems using exclusively Peterson equipment. **IMPORTANT:** It is essential that when using a PETERSON PULSE POWER SUPPLY or other auxiliary power supply for operating the Stop Action Magnet coils, an UNFUSED connection must be made between the SAM NEG terminal on each combination action mother board and a negative terminal of the auxiliary power supply (DIV NEG terminal on a Pulse Power Supply).

5) **Piston Button common conductors:** A single 6 Amp fuse should be provided in the circuit that feeds the common side of all piston buttons. Wire as small as #28 AWG may be used for piston wiring when used with Peterson combination actions.

6) **Expression and Crescendo Shoe contact feeds:** These conductors should also be fused at no more than 6 amps according to our interpretation of the NEC®. Wire size required will vary depending on the type of load and the length of the run. If Peterson solid state systems are connected to the contacts and if no run is longer than 25 feet, then #24 AWG conductors should be adequate. Heavier loads such as coils may require larger gauge wire and possibly special fusing arrangements.

7) **Orga-Plex™ Switching Systems:** Except as detailed in the paragraphs numbered 1 and 3 above, and the use of spares in the main cable to send DC voltage to the console, we believe that no installer-supplied fusing is required for Orga-Plex™ switching systems.

8) **Heavy current main conductors:** The NEC® requires that main supply conductors be at least #14 AWG. We recommend that main, heavy conductors be of adequate gauge to carry the maximum current that the supply (rectifier) is capable of providing through them, or that a fuse be used right at the supply to limit current so that it doesn't exceed the rated capacity of the wire. It is important to avoid a situation where the main power supply to some parts of an electronic system is interrupted, but the supply to other parts remains intact. Therefore, avoid fusing separate wires branching off directly from the main power supply. Instead, use a single large fuse at the rectifier if you wish to fuse the circuit at this point.

WIRE SIZE SELECTION GUIDE

The following information is provided as a guide to selecting the appropriate wire size for each circuit branch. Actual voltage drop across a long length of wire may be determined by comparing the voltage measured between positive and negative leads at each end of the run. The current that a wire carries may be measured with an ammeter in series with the wire at any point in the circuit. The following formulas will help you **calculate** voltage drop and current draw if measurements are not practical. Regardless of whether you calculate or measure current and voltage, it is important to understand the units that go with the numbers you are using. **The formulas that follow assume that voltage is expressed in Volts, current is expressed in Amperes (or "Amps"), and resistance is expressed in Ohms.** However, you may run across numbers expressed in different units. For example, the scale on a multi-meter may be expressed in the unit "millivolt", or "mV", which is 1/1000 of a volt. Similarly, "milliamp", or "mA", and "milliohm", represented by a lower case "m" followed by the Greek letter Ω (omega), are commonly used. To convert millivolts to volts, divide the millivolt number by 1000. For example, 2200 millivolts is equal to 2.2 volts and 400 mV is equal to 0.4 V. Of course, the same conversion applies to milliamps and milliohms.

(1) Determine the resistance of a wire with a certain length and gauge, R(wire), using the chart in Table 2 (Page 7). **Remember that the total length of both feed and return wires must be considered.** This may be thought of as the "round trip" length of the circuit.

(2) Determine the equivalent resistance, R(equiv), of any sets of multiple coils in parallel. Two coils of the same value in parallel have an equivalent resistance of one-half that of either coil individually. The universal formula is:

R(equiv) = 1 divided by (1/R1 + 1/R2 + ...)

where R1, R2, etc. are the resistances of each of the coils that are in parallel. If only a single coil is used in the circuit, use its resistance as R(equiv).

(3) Calculate the total combined load in the circuit, R(total), by adding the resistance of the wire to the equivalent resistance of the coils.

R(total) = R(equiv) + R(wire)

(4) Calculate the current that the wire will carry, I(wire), by dividing the source (rectifier) voltage, V(source), by the combined load.

I(wire) = V(source) divided by R(total)

(5) Calculate the voltage drop across the wire length, V(wire), by multiplying the current that the wire carries by the resistance of the wire.

V(wire) = I(wire) x R(wire)

(6) The voltage available for operating the load is, of course, the source voltage minus the voltage drop across the wire. A further voltage drop of one or two volts is typical in solid state equipment using semiconductors like diodes and transistors, such as a combination action. Therefore, you should select a wire size that will limit voltage drop to only one or two volts so that an adequate level is available to operate the load. Refer to the accompanying tables.

Definition of symbols used:

R(wire) is the resistance of a wire in Ohms.
R(equiv) is the equivalent resistance of more than one wire or coil in parallel, or the resistance of a single coil or wire if no others are in parallel with it, in Ohms.
R(tot) is the total combined resistance of all coils in parallel, and the wire, in Ohms.
***I(wire)** is the current that a wire will carry, in amps.
***V(wire)** is the voltage drop across a wire in volts.
***V(source)** is the voltage of the source (usually a rectifier)in volts.

* For some reason, the letter "I" is universally used to represent current in electrical formulas. Both "V" and "E" are accepted as representing voltage.

1990 NATIONAL ELECTRICAL CODE
ARTICLE 650 - PIPE ORGANS

650-1 Scope. This article covers those electrical circuits and parts of electrically operated pipe organs that are employed for the control of the sounding apparatus and keyboards.

650-2 Other Articles. Electronic organs shall comply with the appropriate provisions of Article 640.

650-3 Source of Energy. The source of power shall be a transformer type rectifier, the DC potential of which shall not exceed 30 Volts DC.

650-4 Grounding. The rectifier shall be grounded according to the provisions in Article 250.

650-5 Conductors. Conductors shall comply with (a) through (d) below:

(a) **Size.** Not less than Number 28 for electronic signal circuits and not less than Number 26 for electromagnetic valve supply and the like. A main common return conductor in the electromagnetic supply shall not be less than 14 AWG.

(b) **Insulation.** Conductors shall have thermoplastic or thermosetting insulation.

(c) **Conductors to Be Cabled.** Except for the common-return conductor and conductors inside the organ proper, the organ sections and the organ console conductors shall be cabled. The common-return conductors shall be permitted under an additional covering enclosing both cable and return conductor, or shall be permitted as a separate conductor and shall be permitted to be in contact with the cable.

(d) **Cable Covering.** Each cable shall be provided with an outer covering, either overall or on each of any subassemblies of grouped conductors. Tape shall be permitted in place of a covering. Where not installed in metal raceway, the covering shall be flame retardant or the cable, or each cable subassembly shall be covered with a closely wound fireproof tape.

650-6 Installation of Conductors. Cables shall be securely fastened in place and shall be permitted to be attached directly to the organ structure without insulating supports. Cables shall not be placed in contact with other conductors.

650-7 Overcurrent Protection. Circuits shall be so arranged that all conductors shall be protected from overcurrent by an overcurrent device rated at not more than 6 amperes.

***EXCEPTION*:** The main supply conductors and the common return conductors.

Table 1. Current Consumption in Amps, Given Voltage and Resistance

	D. C. VOLTAGE										
LOAD RESISTANCE IN OHMS	10	11	12	13	14	15	16	17	18	20	24
10	1.000	1.100	1.200	1.300	1.400	1.500	1.600	1.700	1.800	2.000	2.400
15	0.666	0.733	0.800	0.866	0.933	1.000	1.066	1.133	1.200	1.333	1.600
20	0.500	0.550	0.600	0.650	0.700	0.750	0.800	0.850	0.900	1.000	1.200
25	0.400	0.440	0.480	0.520	0.560	0.600	0.640	0.680	0.720	0.800	0.960
30	0.333	0.366	0.400	0.433	0.466	0.500	0.533	0.566	0.600	0.666	0.800
35	0.285	0.314	0.348	0.371	0.400	0.428	0.457	0.485	0.514	0.571	0.685
40	0.250	0.275	0.300	0.325	0.350	0.375	0.400	0.425	0.450	0.500	0.600
45	0.222	0.244	0.266	0.288	0.311	0.333	0.355	0.377	0.400	0.444	0.533
50	0.200	0.220	0.240	0.260	0.280	0.300	0.320	0.340	0.360	0.400	0.480
55	0.181	0.200	0.218	0.236	0.254	0.272	0.290	0.309	0.327	0.363	0.436
60	0.166	0.183	0.200	0.216	0.233	0.250	0.266	0.283	0.300	0.333	0.400
65	0.153	0.169	0.184	0.200	0.215	0.230	0.246	0.261	0.276	0.307	0.369
70	0.148	0.157	0.171	0.185	0.200	0.214	0.228	0.242	0.257	0.285	0.342
75	0.133	0.146	0.160	0.173	0.186	0.200	0.213	0.226	0.240	0.266	0.320
80	0.125	0.137	0.150	0.162	0.175	0.187	0.200	0.212	0.225	0.250	0.300
85	0.117	0.129	0.141	0.152	0.164	0.176	0.188	0.200	0.211	0.235	0.282
90	0.111	0.122	0.133	0.144	0.155	0.166	0.177	0.188	0.200	0.222	0.266
95	0.105	0.115	0.126	0.136	0.147	0.157	0.168	0.178	0.189	0.210	0.252
100	0.100	0.110	0.120	0.130	0.140	0.150	0.160	0.170	0.180	0.200	0.240
110	0.090	0.100	0.109	0.118	0.127	0.136	0.145	0.154	0.163	0.181	0.218
120	0.083	0.091	0.100	0.108	0.116	0.125	0.133	0.141	0.150	0.166	0.200
130	0.076	0.084	0.092	0.100	0.107	0.115	0.123	0.130	0.138	0.153	0.184
140	0.071	0.078	0.085	0.092	0.100	0.107	0.114	0.121	0.128	0.142	0.171
150	0.066	0.073	0.080	0.086	0.093	0.100	0.106	0.113	0.120	0.133	0.160
160	0.062	0.068	0.075	0.081	0.087	0.093	0.100	0.106	0.112	0.125	0.150
180	0.055	0.061	0.066	0.072	0.077	0.083	0.088	0.094	0.100	0.111	0.133
200	0.050	0.055	0.060	0.065	0.070	0.075	0.080	0.085	0.090	0.100	0.120

Table 2. Resistance Per Length of Various Wire Sizes

Source: National Bureau of Standards Handbook

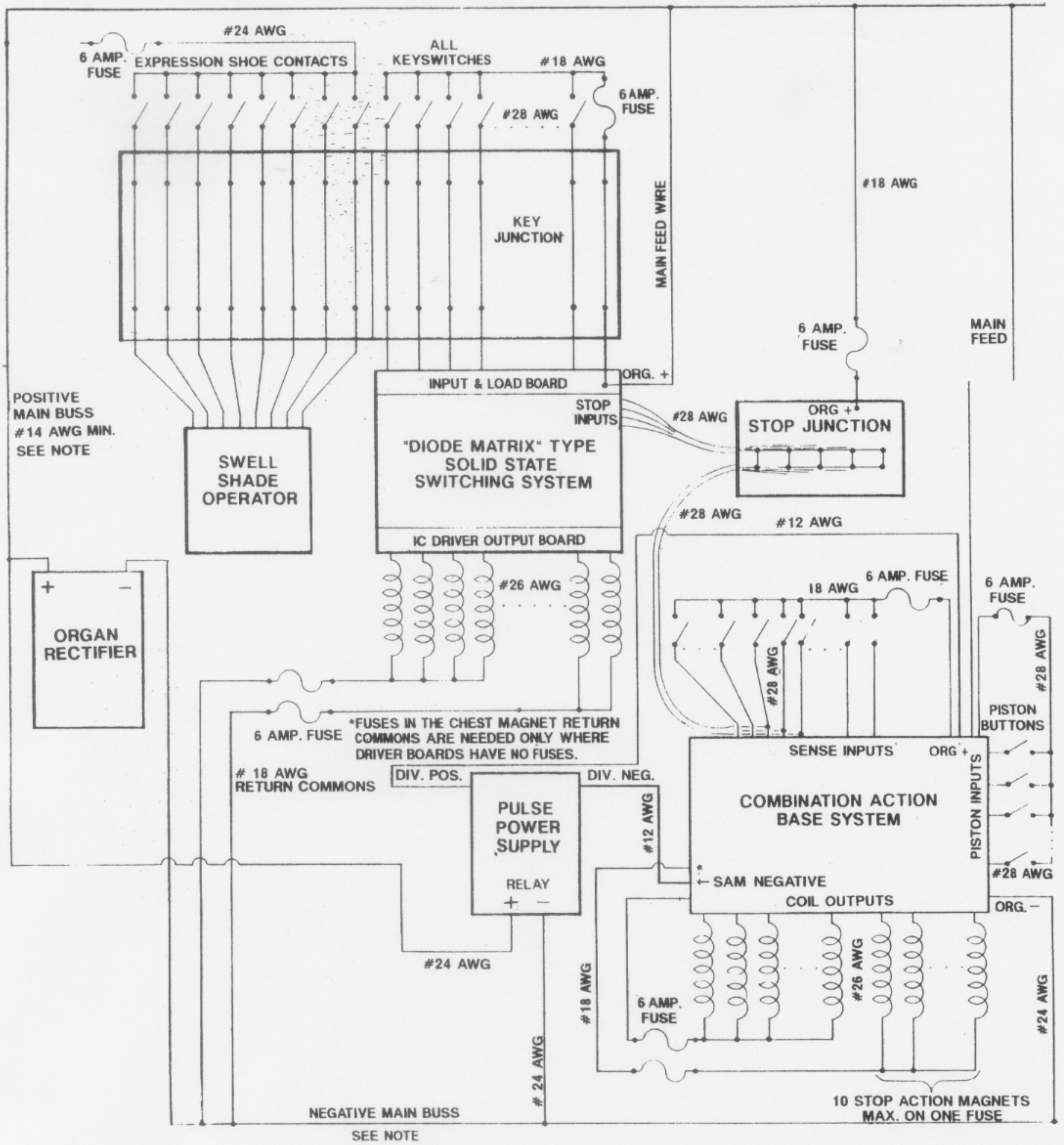
Wire Size ▼	Ohms Per 1 ft.	Ohms Per 5 ft.	Ohms Per 10 ft.	Ohms Per 25 ft.	Ohms Per 50 ft.	Ohms Per 75 ft.	Ohms Per 100 ft.
28 Solid	.0653	03265	.653	1.6325	3.265	4.8975	6.53
26	.041	.205	.41	1.025	2.05	3.075	4.1
24	.0257	.1285	.257	.6425	1.285	1.9275	2.57
22	.0162	.081	.162	.405	.81	1.215	1.62
20	.0101	.0505	.101	.2525	.505	.7575	1.01
19	.00805	.04025	.0805	.20125	.4025	.60375	.805
18	.00651	.03255	.0651	.16275	.3255	.48825	.651
16	.0041	.0205	.041	.1025	.205	.3075	.41
14	.00257	.01285	.0257	.06425	.1285	.19275	.257
12	.00162	.0081	.0162	.0405	.081	.1215	.162
10	.001018	.00509	.01018	.02545	.0509	.07635	.1018
8 Std.	.000653	.003265	.00653	.016325	.03265	.048975	.0653
6	.000410	.00205	.0041	.01025	.0205	.03075	.041
4	.000259	.001295	.00259	.006475	.01295	.019425	.0259
3	.000205	.001025	.00205	.005125	.01025	.015375	.0205
2	.000162	.00081	.00162	.00405	.0081	.01215	.0162
1	.000129	.000645	.00129	.003225	.00645	.009675	.0129
0	.000102	.00051	.00102	.00255	.0051	.00765	.0102
2/0	.0000811	.0004055	.000811	.0020275	.004055	.0060825	.00811
3/0	.0000642	.000321	.000642	.001605	.00321	.004815	.00642
4/0	.0000509	.0002545	.000509	.0012725	.002545	.0038175	.00509
50 mcm	.0000431	.0002155	.000431	.0010775	.002155	.0032325	.00431
300	.000036	.00018	.00036	.0009	.0018	.0027	.0036
350	.0000308	.000154	.000308	.00077	.00154	.00231	.00308
400	.0000270	.000135	.00027	.000675	.00135	.002025	.0027
500	.0000216	.000108	.000216	.00054	.00108	.00162	.00216

Table 3. Lengths of Various Gauges Wire to Drop 1 Volt When Carrying 1 Amp

Wire Size (AWG)	Length For 1 Volt Drop (Feet)
28	15.11
26	24.04
24	38.17
22	60.61
20	96.15
18	153.85
16	243.90
14	384.62
12	625.00
10	1000.00
8	1562.50
6	2500.00
4	4000.00

Divide this number by the maximum number of amps that the wire will carry to find the wire length that will drop one volt.

FUSING & LAYOUT OF A TYPICAL ORGAN CONTROL SYSTEM



*NOTE: # 14 AWG MIN. FOR NEC COMPLIANCE. USE LARGER SIZE IF THE CONDUCTOR WILL CARRY MORE THAN 15 AMPS OR FOR RUNS LONGER THAN 25 FEET.

WARNING: WHEN USING A PULSE POWER SUPPLY, IT IS **VERY IMPORTANT** THAT THE "SAM NEG" SCREW TERMINALS ON THE COMBINATION ACTION MOTHER BOARDS ARE CONNECTED DIRECTLY TO THE PULSE POWER SUPPLY DIVISION NEGATIVE TERMINAL. DO NOT FUSE THIS CONNECTION.