Myers launch controller –REVISION 5a

By Scott Myers 4/9/07

This document is to introduce my launch controller design to the rocketry world. It is also intended to spark discussion on design topologies, safety considerations, functionality, practicality and cost of launch controllers amongst hobbyists. I have looked at several designs now in use and find that I was unsatisfied with those designs. Many are good, but they seem to be lacking either in one area or another, in my opinion. Since I am now looking to build a controller for my sons and me, I would like to get feedback from others interested in launch controller design. I have detailed my thought process to help myself as I laid out my design and I hope others find this helpful and informative.

Two of the more important aspects of launch controllers that everyone concerns themselves with are simplicity and cost. My design DOES NOT fall into the simple or inexpensive category. I have given up simplicity in favor of safety, flexibility and ease of operation. If you are looking for a simple launch controller at a low cost, then you will need to look elsewhere. This project is more for the electronic hobbyist or serious rocket system enthusiast that wants maximum safety and performance. It will involve some electronic calculations and bench experimentation to make sure the circuits work properly before building the controller. Also, one should not enter into considering building this design from a low cost "student" level point of view. While not in the thousands of dollars category, it will certainly cost a few hundred dollars to build ultimately, not including any printed circuit boards that the builder has made. So be a warned of what you are getting into if you decide to move forward with building this project. However, reviewing the discussion and design herein certainly has merit even if you opt for a simpler and less expensive route.

A launch controller is designed to do one thing – ignite rocket motors. This seems simple enough to be sure. But how many times have we all seen controllers or igniters fail for one reason or the other? Most of the times a proven system used by any club works just fine. But what REALLY happened when a cluster powered rocket doesn't ignite properly? The current designs I have seen seem to make a lot of assumptions about igniter power requirements and sadly lack for safety, indicators and interlock systems. This needs improvement to be sure.

I found that a design from Steve Robb is an excellent foundation on which to base a new design. It is simple and contains all the basic elements. I have heavily modified many aspects of Steve Robb's launch controller circuit to come up with my own circuit. I'll modify this document as I progress in my design modifications and as sections of my circuit are tested and changed.

Steve Robb's original design centered on the following design criteria.

a) Control 8 pads
b) Ability to check igniter continuity at the pad as well as at the console
c) Maximize safe operation
d) Robust construction
e) Self contained – no external batteries
f) Flexible and expandable
g) Have maximum power available at the launcher clips

I have followed most of Steve's design criteria, with the exception of points a & e above.

- a) - The unit I will build will most likely have control for 6 pads or under. However, the basic design will be completely expandable to as many pads as needed, even if it has already been built. This is ideal for clubs that want to expand their launch capabilities after already building the launch controller.
- b) - My design topology will not use internal batteries. Rather I will use external battery packs. This change is to reduce the weight of the controller box and pad side box, increase

ease of portability, eliminate any possibility of battery leakage (as sealed gel and lead-acid batteries are known to do) which would harm the internal electronics, allow quick changeovers in the field in the event of dead batteries and allow easy charging and testing of the battery packs independent from the controller.

I have explored many aspects of the controller design, including:

1) Igniter continuity, igniter current protection & LED indicator circuitry
2) Cabling & shielding
3) Battery sizing and configurations
4) High current switching
5) Igniter dependability and voltage drop for cluster ignition
6) Grounding topologies to reduce stray currents – looking at grounding out igniters for safety
7) Strobe circuitry for range closed warning
8) Connector and switch choices
9) Radio control modification
10) Cabinetry, carrying cases & portability

There may be other avenues that may open up as I further explore those areas above.

First I would like to recognize Steve Robb for his hard work on his original design. His basic design looks very solid and well thought out on paper and I am told worked quite well. The launcher he actually built is beautiful physically to say the least. While Steve seems to have disappeared from the world of rocketry (if you are out there Steve, let us know), his design lives on. When he designed this, he was a member of the Minnesota Amateur Spacemodeler's Association (MASA). His original design can still be found on their web site – www.masa-rocketry.org. However, upon reviewing the design, I have found that there are some parts of the circuit that cannot be built as described on the original schematic. There are also parts of the circuit that raise questions. Coming from a background where I worked for a government contractor building missile detonators and building testing equipment for them, I see some areas where safety could be improved in critical areas. Being the continual tinkerer, I thought I would take a crack at answering some questions while I work on my own launch controller design. Do understand that I have been out of electronics for over 20 years, so I am a bit rusty and not up to full speed on the latest technologies. Hopefully if you decide to delve into my design, you would double check and test my circuits before putting them into service. Hopefully by the time you get to this document, I will have proven out all my circuitry. But in the event you get one of these early copies, be **WARNED**! **The circuits shown herein are all theory and have not been built or tested yet. Steve Robb's original circuit has been built and put to use. This document is intended for experimenters only and as such, you build these circuits herein at your own risk.** You will need to download Steve's original complete circuit for some of this document to make sense.

Igniter continuity, Igniter current protection & LED indicator circuitry

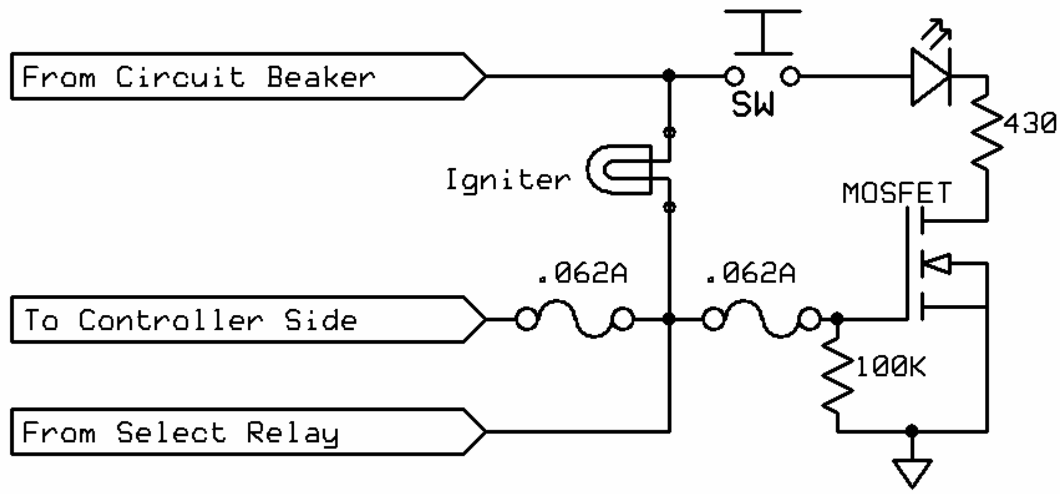
The first question I had as I examined Steve's design was of the MOSFET device for triggering the continuity LED's. Steve calls out a 1N3502 MOSFET on his schematic. Such a device number doesn't exist, nor did it ever as far as I can tell. Certainly, a MOSFET device is the right type to use with its high gate impedance and nearly no gate current. Running a cross reference on a 3502 number under MOSFET, there comes up 4 possibilities on www.mouser.com, such as a Fairchild FDB7030BL. But the 3502 series MOSFETs are massive overkill, as the smallest of which is a 30 amp device!!! They are also typically either a TO-220 or TO-263 case, which requires a mounting screw and heatsink, which again is overkill by a huge factor. We could drive about 1200 LED's with this 30 amp MOSFET. Since we need less that 25 mA through almost any typical LED, something much smaller without need of a heatsink or special mounting seems more appropriate. Looking at it from a redesign standpoint, I found many MOSFET devices in standard TO-92 package that are more than sufficient. These devices are typically at least 200-300 mA continuous current devices and still provide more than 8-12 times the current required by a typical LED. Further, they are very small and lend themselves to PCB or breadboard mounting with no heatsink. A fewe of these devices are as follows:

- Zetex ZVN2120A
- Fairchild FQN1N60C
- Fairchild BS170 – Best choice considering its $0.17 cost and R_{DS} of 1.2 Ohm.

I have added a couple changes to the gate side of the MOSFETs. A 100K resistor was added to ground from the gate input of the MOSFET. I also added a 62 mA fast-blow pico fuse to the input of the gate to the MOSFETs. This is not to protect the MOSFET, but rather to provide protection for the igniters through the continuity detection circuitry. One of the biggest safety risks of installed igniters is checking continuity while near the pad. If anything shorts out in the gate input of the MOSFET circuitry, you will ignite the igniter. Not good. So since 62 mA is a safe current for an igniter and since the MOSFET gate circuit should pass less than 1 mA, this should be an acceptable value. This is the smallest value pico fuse that is commonly available that I can find. These are specified to blow in 3 mS when 200 mA is reached. This should keep the igniters on the pad in the safety zone. The downside is that if they blow, it will disable that continuity check on that channel until the fuse can be replaced, but will still allow the channel to be used for launching. A further modification could be made that would automatically disable that channel of the pico fuse blows. I will explore this at a later time.

I have changed the location of the dropping resistor and LED to the drain side of the MOSFET. I threw in a 430 Ohm resistor value, but this is dependent upon the forward voltage of the LED chosen and desired brightness. Some experimentation on LED brightness and current, as well as looking at the MOSFET voltage saturation specifications needs to be examined carefully to determine exact resistor value here. What is for sure is that we can use standard ½ watt metal film resistors since we have very low power requirements through this part of the circuit.

Following you can see a modified version of a section of Steve's basic schematic of the pad side relay box. You can see the changes I have made if you compare this to Steve's original schematic. Note that my final LED circuits are considerably different, but this is a good modification to Steve's original circuit if you wish to build his exact circuit.



The LED circuit above still stays quite simple and isn't much of a modification of Steve's circuit, yet adds additional safety to the igniter circuit. (Note this is not ultimately what I design into my own circuit, but does help explain and improve Steve's circuit.) It also makes it practical to build this section of the circuit with commonly available components at a reasonable price.

Steve is correct in that all the incandescent lamps should be converted to high output LED's. However, a 13,000 mfd LED is not a common or cheap LED. Rather, typical high output LED's are from 3,000 to 6,000 mfd. A 3,000 mfd LED is typical and easy to see in bright sunlight. If one went to high power LED's, such high outputs might be attained, although I have not researched it. But seeing that high power LED's are generally more than $5 each and would require we go back to higher current draw MOSFET's, I ruled them out.

For the controller side of the schematic, I will remove both the "continuity" and "selected" incandescent lamps and replace them with LED circuits as Steve suggested. The continuity LED is similar to the continuity LED circuit on circuit #1 above. Other LED circuits are much simpler in that one simply replaces the incandescent lamp with an LED followed by a resistor to ground. The value of this resistor may be approximately 430 Ohms, as the LED current limiting resistor in circuit #1, but this too will require experimentation. Since I will be using different colored high intensity LED's, the forward voltages will be different so it will require that I use different resistors to get the correct current flow and the same perceived brightness'.

Finally, there is the "pad power" LED shown on Steve's schematic. It would seem that its dropping resistor should also be changed to the 430 ohm range, depending again on the forward voltage value for the LED chosen.

Another change that I feel is VERY important to make is the arrangement of the continuity check circuit in its entirety. The original design calls for latching the main circuit breaker across the igniters and then pushing a switch that connects the LED's to the main power via the MOSFET. This looks good from an operator's standpoint, but I am not comfortable with this from a safety standpoint. A much better arrangement is to power the drain-source side of the LED circuit when the main breaker is latched and then use a momentary contact switch with a current limited circuit across the igniter. This greatly reduces any chances of leakage voltages causing a premature ignition due to a shorted component. I have redesigned this portion of the circuit greatly to include a low current relay circuit.

Cabling & Shielding

A bit more attention should be given to the cabling and wiring on the controller system. Steve makes little mention of the wire and cabling choices, but it certainly should not be overlooked as being very important. This is very often an area that is not given enough attention in circuit design. Often times, designs are laid out with only cursory thought given to the wiring. Amperage capacity of the wire is often times all that is considered. More should certainly be considered, considering the safety required with this system and the costs involved.

The areas I will consider will be:

- Amperage capacity & heating
- Capacitance
- Shielding

Amperage capacity is of course the first item everyone considers that delves into such projects. In this project, we have the main control cable “snake” which connects the pad side box to the control box. Most of these wires will carry less than 100 mA each. Only 1 wire has the potential for more current which is the controller power feed, which may be up to 1 amp. This is dependent upon the number of pads designed in. (You will note that my design feeds all power from the pad side box, which I will discuss later in this document.) Several wires in the cable can be run in parallel to allow for this greater amperage. Cables are also commonly available with conductors of different sizes. I will probably opt of the latter, unless it is cost prohibitive.

Capacitance is not a big issue in our application. However, if the main cable chosen is very long, it can become an issue. What happens is that adjacent lines can begin to pick up noticeable voltage differentials and small current bleed due to the capacitive effect of the long lines lying side by side. One safety precaution to use would be to use cabling that has individual shields on wires and drain them only at the pad end box. This would negate any potential problems. But as I said, this is not a big issue in our application.

If shielded conductors in our main cables are used, this would allow for additional protection in the event of a conductor short. The separate ground path would let the current quickly rise to ground blowing the fuse protecting that line. The alternative would be for the adjacent wires to short to each other with unpredictable results. Again, this is not normally a problem, but this should always be considered in an application where human safety is an issue.

Wire sizes are not currently chosen in my schematic. I will review this at add it to this document at a later time.

REVISON 5 Addition

Choosing commonly available cable for the main cable between the two boxes is tougher than I had hoped. It comes down to availability VS cost. Also to be considered is the appropriateness of the wire. I wanted something that is flexible even while cold with a tough outer jacket. So this means that the more common PVC jacketed cable with 7 strands per conductor is not a good choice. That type of wire is intended for installation, is too stiff and the outer jacket is too thin and easily damaged. I decided to look for cable with just one overall outer shield for cost purposes. Even this was no help. What I have ended up choosing at this point is standard audio “snake” cable. It meets all the criteria needed in flexibility and toughness. It unfortunately has the wires in pairs with a ground wire with common shield around each pair, so dealing with the shields at one end will be a bit of work, but it can be overcome easily enough. I would like that the shields only be connected at the pad side and not the controller side for a proper grounding scheme, but I will end up making a trade-off at this point and grounding both ends to keep wire cost as low as possible. Since we are dealing with signals in the volt range, this should not be a problem. The main place this type of cable lacks is that each conductor is only a 24 gauge wire, so the main power feed to the controller box and the ground return must use more than one conductor. I will choose to use 2 pairs for the power and those two pair’s ground wires for the common ground return so that the proper conductor ampacity is achieved. 1 pair is probably enough if one goes with my design that uses all solid state for pad circuits, but one pair is a bit more marginal than I like. Since I will be building my controller with 4 pad capability, I will require 14 conductor paths between the controller and pad boxes. This is 12 paths with 1 wire each and 1 path using 4 wires for power plus several ground wires. I can use any of the ground wires in with the pairs. This brings me to a total of 16 conductor paths plus 2 grounds. Therefore, I can use an “8 channel” snake cable, which is a common size. The cost is a bit more than I had anticipated at about $120 per 100 feet, but I will keep my eyes open for other possibilities.

Battery Sizing and Configurations

Steve’s original design calls for (4) 7 Ah (amp hour) batteries; two at the controller side and two at the pad side box. He also used batteries for spade type terminals.

For the controller side box, a battery capacity of 12 Ah seems very high. If we consider we might have 20 LED’s and 10 primary relay coils energized simultaneously, we might see about 1 amp being pulled from the battery on the controller side. But do remember that the select relays will generally only be on one at a time, except in the cases of simultaneous multiple launches, but this is a more rare occurrence. Even in this case, the most time one would expect for all the relays to be on would be 5 minutes or less.

For the pad side box, 14 Ah may actually be more than the total power requirement, as the only time power is drawn from these batteries is when the continuity is checked pad side and during actual igniter ignition. However, current draw during the few seconds of igniter ignition can be extremely high. In the case if igniting cluster arrangement, the amperage draw can be extremely high. Therefore, it is most likely a necessity to go with a physically large battery or multiple small ones to have plate areas large enough to produce the 100 amp approximate current requirement necessary. I will go into total current requirements in the next section.

I am not a fan of using 2 sets of batteries. The problem with this is that the controller and pad side batteries will drain at different rates and will therefore have slightly different voltage potentials. Since I will be using a central grounding system topology (see under the heading grounding topologies later in this document) and not using optoisolation, I do not want more than one voltage potential to ground anywhere in the system, as this begs for trouble. Rather, I will use one battery(s) at the pad side which will provide all the power required for the entire system. This will also keep battery replacement simpler and less expensive.

Doing some "guestimations" using Steve's original design calculating total current draw, I looked at 8 loaded pads and expected worst case scenario of power requirements for a 10 hour launch day, with 20 minute launch windows, followed by 20 minute pad reloads. This is 15 launch windows for the day each with a high side maximum of 1 amp being drawn continuous with up to 100 amp surges for 3+ seconds x 8 launches. (I know this is high, but I am trying to error on the high side, as you never want to run out of power during a launch day.) This is an approximate .5 Ah drain rate since we have a 50% duty cycle, if 20 minutes on and 20 minutes off is an accurate estimate. And since we would have 10 hours at a .5 Ah drain rate, we would require a battery with a minimum rating of 5 Ah. Of course, we would never want to size our battery for the minimum requirement, so I will pick a 200% duty cycle capable battery, which would bring the battery to a 10 Ah rating.

Because I will be using external batteries, some very heavy wiring will be necessary to handle the possible 100 amps or greater current rush on a large cluster motor start. I will opt to go with welder cable wire and its associated connectors. This type of wire is common and its connectors are relatively cheap. It is also tough, as it is meant to be dragged around on a dirty shop floor, so it will handle field conditions with no problem. It is also limp so it bends and lies easily. Welder cable connectors are also robust and cheap. I will explore other connector configurations to insure proper polarity is followed, as welder connectors do not have a "fool-proof" polarity connector design.

REVISION 4 addition

I contacted the technical department at batteries plus (www.batteriesplus.com) with the launch day worst case scenario power requirements I outlined herein. I discussed total Ah draw over a 10 hour launch day, current inrush and dwell times in detail. The power requirements under an absolute worst case scenario call for every bit of a 27 Ah battery, if every launch were to be high current draw as described herein. The total Ah requirement assumes the relatively high drain of standard relay coils, not MOSFET switching circuits as described later in this document. Also it is important to note that they recommend that the terminals be only the 3/8" bolt type, as this is what is required for the high inrush under a multiple igniter cluster launch condition. What we basically ended up with is a sealed gel cell automotive type battery with side terminals that weighs about 45 lb. Such is the price we pay for a high current rush 12 VDC application. The most important thing to note is the "cranking amp" ratings, as this is what is important to make sure we get maximum power at the igniters. Based on the possible current requirements of 8+ igniters in parallel and ignoring any shorting possibilities at launch, we need at least 200 amps available. Taking shorting into account and a current protection scheme at the pad, we need a battery capable at least double for a total of 400 amps. Luckily, most batteries with 27 Ah in a gel cell configuration will have well over 400 "cranking amps" capacity. If the launch day will be shorter or no large cluster launches will happen, the battery can be downsized accordingly. Unfortunately, there is usually no way to determine who will show up and with what on launch day. So having a battery sized for approximately 27 Ah on hand on launch day seems appropriate, but this is a judgment call you will have to make.

REVISION 5 addition

The engineers at Batteries Plus finished doing some calculations on our demands placed on a battery. Ignoring total ampere-hour requirements, the main thing they feel we need is a battery capable of high current demand for a short period of time. The battery type required is one that uses "thin plate" technology, as opposed to the cast plates of standard lead-acid batteries. They suggested their "Odyssey" battery. To give you an idea of what this battery can do, let's look at a typical PC625 model. This battery can supply 265 cold-crank amps, yet supply 625 amps for 5 seconds and not drop below 7.2 Volts at the terminals during that 5 second period. Lead-acid batteries cannot do that! Not to mention it weighs less than half of what a lead-acid does and it won't leak anything because it is a dry rechargeable battery. It will also get up to current in just a couple of milliseconds, whereas a lead-acid will take 50-100 mS or so at full load. It is also designed to take much higher shock and vibration than lead cells, as it was originally designed for ATV's. Plus it's price is quite good for its Ah rating. Nice. This type of battery would seem to be the winner hands down for our application.

So if I consider this to be the battery of choice and I use the 7.2 VDC as my minimum "sag" voltage, I can now go back and consider capacitor and resistor values and how this will affect MOSFET and relay coil switching. I will review this as time allows.

High current switching

In a launcher application, the need for high current capability switching is paramount. As I discuss in the following section, the need for very high current flow with the majority of the power dissipation going across the igniters is key.

There are 4 issues that I know of:

- Relay coil power consumption
- Voltage drop due to current rush across the igniters causing relay drop out and rapid contact cycling
- Availability of high current relays for 12 VDC service
- Contact resistance over time

Relay coil power consumption

Commonly available high current automotive type relays satisfy the current requirements on the contact side, but require current consumption by their coils. Typical relays that are used like those made by Bosch (Bosch Product # 0 332 209 137 typ.) require about 160-180 mA to keep the coil energized. In my design in a worst case scenario, an 8 pad launch controller with all select and continuity relays engaged would draw nearly 3 amps, not including LED circuits as well as arming, cap discharge and ignition relays. While our battery system can be sized to handle this, we might want to consider a different switching scenario that requires much less energy to keep enabled. At a minimum, we need to keep this in mind.

Voltage drop due to current rush across the igniters causing relay drop out and rapid contact cycling

Here is a big problem. Without talking to Steve Robb, I would venture to guess that this combined with the relay coil power consumption were the reasons a separate battery system was used in Steve's design in the controller side. This also explains to some degree why Steve used 14 amp-hours in the controller box. Some more calculations will need to be done to see if I can still stay away from a 2 power source solution. I believe it can be done and still use standard relays.

Availability of high current relays for 12 VDC service

There are only a couple of brands of DC relays for high current that are available for reasonable cost. This type of relay is commonly found for use in automotive applications. They have become quite popular for switching on high current draw audio amplifiers. A 50 amp relay is the most common, with some 70 amp units available. These relays meet the requirements of our application… barely. The inrush of current can easily exceed several hundred amps for several hundred milliseconds when igniters short out after ignition.

Contact resistance over time

When the contacts of relays change condition, they slowly oxide, especially when placed under great load. This normal aging causes increasing resistance across the relay which takes power away from the igniter and speeds the break down of the contacts even further. This heating and shortening of contact life, especially when the relay is de-energized during a high current event, is a problem and requires periodic replacement of the relays. Since we stress the relays well beyond their expected normal operation parameters, I would expect premature failure.

Alternate solution to relays

I first looked for power solid state relays as a pre-built component. They are available as MOSFET relays, but seem to suffer from the problem of drain-source resistances of over 10 ohm, which limits their current flow to just 1 amp. These will obviously not work for our application.

A better solution can be found in the form of a discrete MOSFET at component level. MOSFET power transistor are available that solve a number of problems. The problems solved include:

Price - $2.00 to $5.00 each, depending upon exact configuration and amperage rating
Size - Small TO-247 transistor package (slightly larger than TO-220)
Low power dissipation – R_{DS} resistances of less than .01 ohm are available standard
No coil power drain – Being a MOSFET device, there is practically no current drain through the gate circuit, unlike the coil requirement of a relay. Therefore, we do not have to worry about how much power is required to keep them switched on, unlike a relay.
Capacitive RC latching – Since there is no drain of current at the gate of the MOSFET, a capacitive RC time dependent latching circuit can be employed to keep the MOSFET switched on for a predetermined period of time, protecting it from switching off during high current demand/low voltage conditions.
No contact deterioration – Transistors do not suffer from the contact breakdown that relays do. Therefore, the life expectance is practically infinite in this application.
Multiple units for higher current – Since these devices are quite small, several of them can be used in parallel for increased current capability. There is also no penalty of additional coil drain current like in a relay circuit when doing so.

A couple of such devices are as follows:
International Rectifier IRFP064N
Fairchild HUF75344G3 – Best choice due to cost of $3.05 each and .006 Ohm R_{DS}.

However, this solution is still a trade off. With an increase in solid state devices, there come complexity issues. The problems created by using MOSFETs include:

Multiple MOSFETs can be required for each relay replacement - A MOSFET as it applies to this application is basically a single pole normally open switch. Therefore, it will require 1 for SPST function; 2 for SPDT function and 4 for DPDT function. This adds considerable complexity to the circuit.
Heatsinks are needed – Power MOSFET's come at the cost of getting very warm under load. We will be loading them for only seconds at a time during an ignition sequence, so they shouldn't get that warm. However, we should still provide a heat sink for each high power MOSFET as a safety precaution.

Other components required – It is never so easy as to just drop a MOSFET in place of a relay. There will be other components such as resistors needed to make them operate properly. If we are to add the voltage sag latching function aforementioned, it will require diodes and capacitors as well.
Interconnection – Since they are small, getting the big wire to its drain & source legs will prove to be interesting. Careful circuit board layout and large traces will be required.
Resistance rise – While under load, the internal junction temperature will rise, increasing power loss at the MOSFET. However, because of the very short duty cycle of our application, this may be something that doesn't cause a real problem.

Clearly, the MOSFET relay replacement solution is possible, but it comes with additional complication. Some experimentation and calculations will need to be done before determining if this solution makes more sense than mechanical relays.

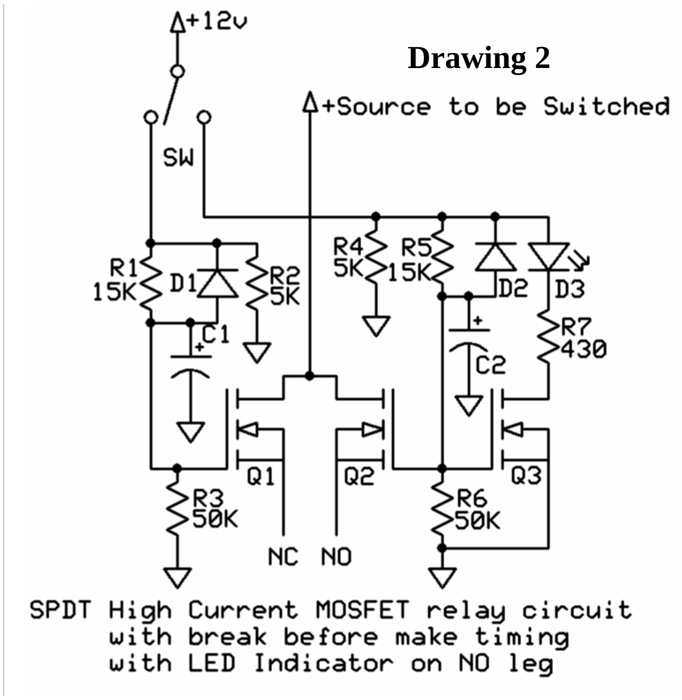
REVISION 4 addition

The use of the SPDT high current relays used throughout my design is problematic. It seems that in the low cost automotive style in 50 amp sizes and above, they are primarily SPST. This means I will have to further complicate my design with additional relays and coil power losses or use an alternative like MOSFET high current switching. I did find high current industrial style SPDT relays commonly available, but at considerably higher cost than the automotive style. (But they are considerably better documented than automotive styles as one would expect.) These industrial style DC relays also have considerably more power loss at the coil than the automotive style as a general rule.

After exploring the possibility of using high current MOSFET, it does seem possible while keeping component cost low. This circuit could potentially replace all high current relays, such as ignition relay R2. It will require building a couple of such a circuits and testing its viability.

One possible circuit is shown in Drawing 2. Keep in mind this is a concept design and needs further scrutiny.

NOTE: I am not an electronic engineer and have not re-educated myself on transistor circuitry as a whole. At the moment, I am limiting myself to N-channel enhancement MOSFET's, as these are the easiest for me to work with. This is most likely the same type originally used by Steve Robb in his original design.



- Q1 & Q2 are high current MOSFET's.
- Q3 is a small TO-92 body device used for turning on the LED indicator(s).

The circuit above has several features that a mechanical relay does not, as mentioned previously. Some are as follows.

- The on or off condition of the high current MOSFET's can be timed. In the circuit above on the "NO" side, the RC relationship between R5 & C2 governs how fast the MOSFET turns on, while the RC relationship between R4 & C2 governs how fast it turns off. With the values shown above, the time it takes to turn on will be approximately 3X longer than the time it takes to turn off. Since both the "NC" & "NO" sides of the circuit are using the same values, this should insure that you have cut off Q1 before turning on Q2 (and vice versa) when the condition of the switch is changed. The exact timing of Q1 & Q2 can be tweaked to just about time value you want.
- The current draw of the gate side of this circuit is far less than any relay. Ignoring the current required by the LED which is required in any case, the total current drawn by the gate circuits at any time is jest a few milliamp, which is caused by the voltage dividers. This can be further improved by using higher values of resistors throughout. Some experimentation will need to be done to determine the practical upper limit of the resistor values. Therefore it is estimated that this circuit uses 15X and 69X less power than relays requiring 40 mA and 180 mA through their coils, respectively. Putting this in real word terms; is we assume that we are drawing about 3A across all relay coils in a worst case scenario, the same condition using all MOSFET switching would use well under 150 mA which is 20X less power dissipation.
- The stiffening circuit for the controller side would provide power to the gates of these circuits for a very long time, compared to the relay solution, while under heavy load on the pad side. The risk of coil drop-out is virtually eliminated, even with a system that uses just one battery as I have it currently designed.
- Current capabilities of such a layout can be easily tweaked. If more current capability is required, additional Q1 & Q2 MOSFET's can be wired in parallel with the ones shown

above. Very high currents can be achieved in this manner for very low cost. (With added complexity.)

- Note that there is no true "NO" condition for the MOSFET's. Voltage must be present at the gate for it to be on. Therefore, if one wants to make sure that some part of the circuit is grounded or connected to another part of the circuit when no power is present, a mechanical relay should be used. There are other types of circuits that would allow for a NO condition to occur with no power, but the ones that come to mind are considerably more complex. This circuit is complex enough as is. Luckily, the only circuits that I believe will need to have a path to ground when no power is present are the capacitor discharge circuits, so this would be just two mechanical relays. There are some low power pre-built MOSFET relays on the market that may solve this problem, but I have yet to explore this.

The biggest problem with the circuit above is that N-channel enhancement MOSFET's usually must have a V_{GS} of about 6 volts in order for the R_{DS} to be close to its minimum and for the full current capability and minimum R_{DS} of the MOSFET to be utilized. We also have to remember that the majority of the voltage drop in the system is required across the igniters for maximum power transfer at the moment of launch. Since the igniters are normally found downstream of the relays, this would mean that there would be practically no voltage drop across MOSFET's. Hence, the MOSFET's would pinch down to find equilibrium to the point that a sizable voltage drop would occur across it, so this is not a good or practical solution without further consideration.

Since the goal of the MOSFET relay replacement is to reduce power consumption (and increase reliability), we should concentrate on where we can put such an arrangement in place that makes the most sense. Even I can do this with my rather limited knowledge of electronics. The best place to use it would be as the select relay, since these are more numerous and will be on for the longest periods of time as a whole, this would be the best place to consider mechanical relay replacement. However, since we have the problem of the V_{DS} as aforementioned, a major reconfiguration will be required. Placing the select relays after the ignition relay next to ground would be necessary. So any relay that has a ground reference on its operating contacts is a candidate for MOSFET replacement. If we do this, we can minimize the number of mechanical relays. Again, we have to look carefully at the practicality of this as we begin to layout and test these circuits.

Replacement of the remainder of the relays will require either further study on my part or someone much better versed in electronic design.

Igniter dependability and voltage drop for cluster ignition

I would like to delve into what happens during igniter ignition and how this affects current draw and voltage drop. During most launches this isn't a big issue, as most launches are single motor launches. So the motor either ignites or it doesn't. If it doesn't, the motor's igniter is reworked or replaced and it is tried again. There is no danger of loss of a high dollar rocket or big safety issues. However, consider a rocket with a large cluster. Nearly everyone will agree that cluster launches can be iffy due to not all the motors igniting. Anyone who has been to a launch where several clusters were ignited during the day has witnessed this problem. To make the impact big in your mind, think about something on the order of a rocket with a central M motor surrounded by six K motors. We are talking about a rocket that can cost in the thousands to build and can weight hundreds of pounds. If it goes off course at launch due to asymmetrical thrust, some serious danger will occur, not to mention the monetary loss. Steps should be taken to insure that all of the motors have their best chance for ignition.

The 100 amps or greater possible current draw I described above requires some explanation. After reviewing the published research done by G-Wiz Partners and others on igniter amperage draw, I find it is not unusual for a common igniter to draw as much as 20 amps for a few milliseconds, with spikes that are much higher. The spikes occur when an igniter has already lit and the two lead wires short together, which is a common occurrence. We need to consider this carefully for cluster launched rockets, as it is an area that needs additional consideration.

This current is not a problem for the batteries Steve chose, but resistive voltage sag may be caused by the battery's terminal type chosen. Looking closely at the available data, a problem can arise when a cluster motor arrangement is ignited. What often happens during igniter ignition is that the two leads of the igniter will short together. This gives a path for all the current to go and the voltage across the igniters could easily drop to 2 volts or lower if the current is restricted in any way from the battery. This would cause all of the current to flow through the shorted igniter, stopping the heating of the rest of the igniters to stop during a brief time. This situation needs to be addressed. Since the batteries chosen were of the spade terminal output type, there is a problem with amperage flow/voltage drop/resistance heating right at the battery. I would suggest that batteries of either the ¼" bolt terminal or "J" terminal be utilized at the pad side box. This would eliminate the voltage drop/amperage restriction at this point. If these types of battery terminals are used and the right interconnect terminals and wire is used, we can rest assured that we can get as much voltage and current as possible at the igniters. (I will discuss battery and relay wiring at a later in this document.) Some research will need to be done on battery maximum current rush and voltage sage on various battery types. I will add this to this document as it is completed.

Another possible solution for a shorted igniter in a cluster motor launch would be to use a large voltage "stiffening" capacitor. This device would allow an extremely high inrush across a short, hopefully blowing out the short, while keeping voltage drop high across the other igniters. Some research will be needed to determine the exact style of capacitor to use. One type that comes to mind is the large electrolytic style used in car audio applications. These are a bit pricey though and other smaller capacitors could be utilized to save considerable cash. I have put one of these capacitors in my circuit. It does add the complication that you have to be careful how this capacitor is charged and discharged. It does require that a current limiting resistor be used for charging and discharging. After it is charged, it should be automatically switched in the circuit without the limiting resistor so that full current is available. This is accomplished via a simple RC timing circuit that is commonly used. I chose to make the time about 30 seconds between when the pad is armed and when the capacitor is switched in, making the pad "ready". This insures a reasonably slow charge of the capacitor and keeps anyone from rushing a launch. It may be necessary to include a low value power resistor while the capacitor is in operation to keep the voltage from sagging too low in the event of a long term dead short or just to limit the maximum current rush allowed from the capacitor to keep it from destroying itself. Some additional work will need to be done to determine this.

The other issue that a stiffening capacitor helps with is battery lag. A battery is a chemical voltage potential device and it takes time for the current to rise and the voltage to return when a large demand is made.

One last item that could be installed for cluster launches would be a parallel current limiting network. This network would be a stand alone device and be installed right at the pad. All igniters would be wired from individual outputs of this device while the pad side box feeds its common input. The ground side of the igniters would be tied together as always. Such a network can be accomplished in several ways.

One of the simplest of such devices is a parallel resistor network. A value of 1 ohm would limit the current to 12 amps per igniter leg if it shorts out. However, the problem with this is that each 1 ohm resistor leg would be dissipating 144 watts at that point! (4) 4 ohm 20 watt wire wound resistors would give you 80 watt continuous dissipation which should survive 144 watts for 3 seconds or so at a cost of under $2.00 per leg, or you could double the resistors in a series/parallel arrangement for $4.00 per leg for 160 watt dissipation with a bit more complexity. If you want to keep it simpler, a single silicone coated 100 watt lugged wire wound resistor can be purchased for about $7.00 each. If you really want to get fancy and have an extremely robust package, an aluminum heatsinked and lugged resistor with mounting feet can be purchased for the $13 each range. I personally would opt for the silicon coated lugged wire wound for relatively low cost and to keep the network system simple. The upshot of such a system is that components do not normally ever have to be replaced. The problem with such a system is that a large part of the power dissipation will occur across the resistor network. Ideally we want 100% of the power dissipation to occur across the igniters. Looking closely at G-Wiz's igniter study, it would appear that standard igniters fall somewhere in the 0.5 to 1.0 ohm resistance range. So 1 ohm resistors will eat up .5 to .66 of the total available power. We also can't go much lower in resistor value as the amperage flow at 12 VDC becomes too high when an igniter shorts. Therefore, the resistor network is not the best way to go.

Another way, and probably the preferred solution, is to go is a current protection network. The simplest version of this is a parallel network of fuses or circuit breakers. Here we use fuses or breakers that will open in a few milliseconds at 30-40 amps. Therefore if a particular igniter leg shorts closed, the fuse or breaker will pop and insure that the voltage drop occurs across the igniters. Without doing further research, I believe the fast-blow fuses will be the way to go over the circuit breakers. The will blow very close to the current they are rated, are very fast and above all, cheap. The downside is you have to check them for continuity and replace blown units at each launch. Circuit breakers could be used if sized properly, but careful attention would need to be paid to contact resistance as well as time VS opening curves. Also, it would be necessary to allow them to come down to ambient temperature before each launch. This is a more complex problem to be sure. They are more expensive than fuses, but will not require replacement under normal operation. Again, some experimentation will need to be done no matter which type is chosen. I will probably choose the parallel fuse network as my current protection topology of choice for cluster launches due to simplicity and cost. Using this topology along with the stiffening capacitor set-up, one would be insured to get nearly full voltage drop across all igniters even in the event of any igniter(s) shorting out. The stiffening capacitor would serve to insure a very fast blow of the protecting fuse with minimal dip in the voltage across the other igniters.

There are other more complex and expensive choices for parallel current protection networks. However, I will rule these out due to cost considerations and sheer complexity. It seems ridiculous to spend more than $25 on such a protection scheme. Also, keeping things simple is always best.

Another possibility for increasing igniter dependability would be to increase the voltage of the pad side box to 24 VCD. This would make available double the voltage drop, hence double the power across the igniters. This should insure a quicker and more even start of the igniters, at least in theory. This would increase the amperage through the igniters considerably however and this may come at the cost of larger/more relays in the pad side box and at a considerably increased cost. However, all this is purely theory and will need to be proven out through experimentation. I will not be going in this direction on my first design.

Grounding topologies to reduce stray currents

Having a background with triggers for missiles (safety arming devices), I am aware of the problems of voltage leakage as it is associated with any type of igniter. While the igniters for rockets are quite safe when it comes to stray leakage currents, it is still a good idea to reduce any possibility of any chance of unexpected voltage potentials and stray currents through the igniters. This is especially important during connection of the igniters when you are physically close to the motors. Eliminating any possibility of this potential stray current is easily accomplished.

There are two situations that need to be considered

- Voltage potential differences between the two leads to be connected to the igniters.
- Voltage potential difference between the ground and the launching system

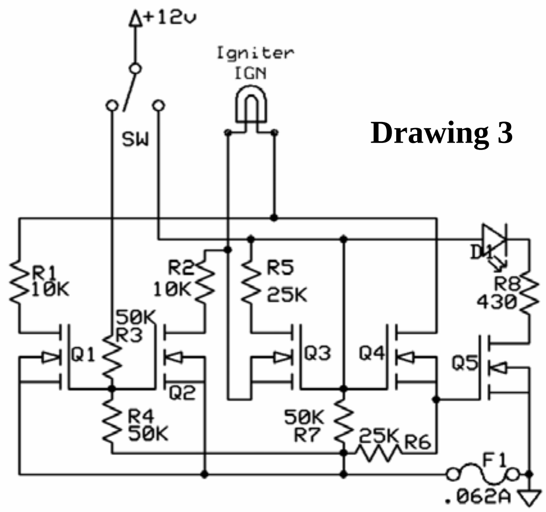
The voltage potential between the two leads is the biggest danger of the two. This problem is easily addressed by tying the two lines together electrically. The best simple way this can be done is by changing the pad selected relay to a DPDT version using the normally closed contacts to tie the two sides of the igniters together while lifting them from the 12 VDC source altogether.

The voltage potential between the system and the ground is the second issue. While this problem is not nearly as big of an issue as the potential differences between the igniter leads, it should still be addressed. Connecting the case of the pad side box to a grounding rod is the solution. It is important that only one ground rod be used at the pad side. Under no circumstances should a ground rod be driven at the controller side. The normally closed side of the now DPDT relay will be tied to the case which is tied to the grounding rod via a current limiting resistor.

REVISION 4 addition

As explored for the high current switching, MOSFET switching may also be a viable solution for the continuity and grounding DPDT relay (Drawing 3). While this is not a high current application, it does require considerable power to operate the mechanical relay. A current of 40 mA is typical of such relays.

A delay for this relay should not be required. Circuit design of this switching set-up keeps any



Drawing 3

Igniter ground safety & continuity indication MOSFET relay circuit with LED continuity indicator

high current conditions from occurring.

This circuit adds two additional MOSFET's to accomplish the DPDT function. While it looks a lot more complex than it's high current brother, it is physically much smaller due to the size of the components. Also like its high current brother, this circuit will need to be built and tested thoroughly.

- The "NO contacts" are Q1 & Q2 while the "NC contacts" are Q3 & Q4.
- Like the high current design shown previously, there is a MOSFET (Q5) used to sense when the "NC contacts" are turned on and energize a LED circuit.
- All of these MOSFET's are small TO-92 devices.
- This circuit requires even less power to operate due to the fact there is no drain caused by timing components. Ignoring the LED circuit portion, the estimated current requirement by the gate side of this circuit is 0.1 mA as it is drawn above. Even the continuity sensing circuit only uses 0.48 mA while in use, as drawn!

Strobe circuitry for range closed warning

While not mentioned under the battery sizing heading, the only other place for current draw would be if the controller battery is being used to actually power the "range closed" warning strobes. Depending upon the strobe size, number and output, this could require considerable power, especially if more than one is ran. Because of this unknown, my design will consider running only a relay that would switch in the strobes own power supply. No power for the strobes will be supplied by the controller. This makes much more sense from a design and reliability standpoint. Therefore, a separate dedicated stand-alone strobe power circuit is expected to be used with this controller design.

Connector and switch choices

I am starting to look and some of the connectors starting with revision 5 of this document. Understand that there are so many choices out there that the substitution list is practically endless. What you use in the end is up to you. Just make sure you consider durability under adverse conditions and safety as your number one design parameters.

Let's start with what will probably be the most expensive of the connectors in the system - the main cable connectors. I would like to stay with Amphenol type round connectors (Sometimes known as Brad-Harrison or Mil style connectors) due to durability and availability. One could utilize D-Sub computer type connectors to save cost, as the Amphenol round connectors are not cheap, nor are they easy to solder for the inexperienced. I will try to stay with the PT bayonet style for ease of connection in a dirty environment, although many like PC style screw connection. What ever you use, make sure it can withstand dirt and water with no risk of shorting if rained on. So this will also mean that the solder end of the connectors should either have a good cable grip ferrule or be potted. I will also choose solder style pins as opposed to the crimp style. While more difficult to build, you don't have to worry about connection longevity.

Other Points

The last three heading points will not be covered at this time. Those points are

- Connector and switch choices
- Radio control modification
- Cabinetry, carrying cases & portability

It is a bit premature to discuss these points. I will cover these points as I begin to work on the prototype. Radio control modification will be the last thing discussed, as this is a very involved subject.

Schematic Notes

The schematic for the controller is on the last page of this document. Some notes about it listed below. I am hoping to get feedback on this circuit. If any errors or improvements are noted, I would certainly like to have them pointed out before I start building sections.

- ➢ All resistor values are approximate. Wattage sizes have not been examined.
- ➢ Fuse / circuit breaker sizes are approximate and have not been fully determined. The number of pads required in the controller will have a bearing on these values.

CIRCUIT REVISIONS

3/27/07 – Revision 1

1) Added approximately 50-80 mS Delay on ignition relay
2) Brought stiffening capacitor discharge relay in parallel with ignition relay and removed automatic delay from it. This added safety to the recharging of the stiffening capacitor between launches by only charging it through the 10 ohm resistor.

3) Changed sensing of "ready" LED to sense directly from stiffening capacitor charge so that time constant (RC) of "ready" circuit is similar to that of the stiffening capacitor across the 10 ohm resistor. However, the value of C1 is an approximation based upon others' experience with this circuit. We are looking for a 50 second time for the "ready" LED's to turn on, as that is the time required to charge C2 to 5 time constants.

3/28/07 – Revision 2

1) Changes made to "ready" LED circuit.
    a. Removed the 680 uF capacitor in favor of a simple voltage divider. The values of the resistors on this voltage divider (R5 & R16) will need to be adjusted when the circuit is tested to achieve a full on condition when the voltage on the capacitor reads more than 12 volts, assuming an actual voltage output of the battery of over 13 volts. A zener diode could be substituted for R16 and the value of R5 changed to achieve a "sharper" turn-on of the LED, but this shouldn't be necessary.
    b. Added a connection between the stiffening capacitor positive pole and the voltage divider MOSFET gate circuit for sensing full charge directly from the capacitor. The circuit now senses when the voltage rise of the main stiffening capacitor is fully charged to turn on ready LED's.
    c. The 3 BJT transistors as previously designed used one for its zener effect and the others for current amplification to turn on the "ready" LED's. These were replaced with a single MOSFET for simplicity.
2) Reconfigured Continuity LED circuit to feed the drain pin of its MOSFET. This should be the best configuration of this device. Changed values of the MOSFET's gate voltage divider resistors so that G_{DS} is approximately 6 VDC. Rewired the controller side continuity LED to utilize this configuration.
3) Changed controller power feed fuse (F5) to a 5 amp size. This is to allow for the high current drain of 20 dc relay coils. This may be reduced in size if MOSFET devices are used as the current switching devices instead of relays.
4) Added remote control jack. This is a "normalized" audio type jack commonly used in patch bays. Bantam and ¼" are popular types, but others exist. This connector breaks the connection of the panel mounted ignition switch and allows the connection of another switch in series. Note that this remote switch will not function without the main panel mounted switch being depressed. This adds another level of safety keeping the remote operator from launching the rocket without the RCO pushing the main ignition switch simultaneously.
5) Added strobe connector to schematic
6) Removed central notes balloons.
7) Changed charging resistor on pad stiffening capacitor to 5 ohm, 10 Watt. This changes the charging time from 60 seconds to approximately 30 seconds.
8) Added stiffening capacitor circuit with 2 relays and back flow diodes to controller side. The RC constant of this circuit is ½ that of the pad stiffening circuit insuring it is fully charged long before the pad is ready to fire. This is to insure relay coils do not drop out for over 2 seconds if igniters short out or the total igniter resistance is extremely low. This assumes the following worst case scenario.
    a. 8 pad multiple launch
    b. Approximately (14) 180 mA relay coils and (8) 30 mA relay coils are energized with a total amperage draw of 2.8 amps for a total coil impedance of 5 Ohm.
    c. Starting C2 capacitor charge of 14 volts.

   d. Relay coil drop out voltage of 3 volts.
   e. 8+ igniters connected in parallel making for a total resistive load of approximately .05 Ohm which requires a 280 amp draw for 0.5-2 seconds from the pad side charging system.
   f. Pad side battery voltage with stiffening capacitor lets the voltage sag to below 2 volts.

9) Increased value of F5 fuse to controller side supply to 5 amps.
10) Changed the main circuit breaker to a 400 amp fuse due to speed of protection, cost and availability.

3/29/07 – Revision 3

1) Changed F3 fuse to 1 amp to power at least 8 continuity relays.
2) Added igniter connector.
3) Tied case grounds of controller and pad boxes together.
4) Added quick disconnect multi-pin connectors and cleaned up wiring layout.
5) Added multiple igniters showing parallel fuse arrangement for cluster ignition. Note that this fuse arrangement IS NOT physically a part of the launch controller, but a separate item located directly at the pad. It should be fed from the pad box via heavy cable, such as welder cable. The grounded side of the igniters is tied together via a heavy buss bar. This too should return to the pad box via heavy cable.
6) Changed individual pad fuse (F4) to 300 amps.

NOTE: The next revision of this document will look carefully at substituting MOSFET circuits for the high current relays. This may not be reasonable due to cost and complexity, but certainly worth exploring.

4/2/07 - Revision 4

❖ This revision reorganizes components into groups and attempts to simplify wiring to make the schematic easier to follow.
❖ The revision of the circuit o should be getting fairly close to the “final” version of the circuit that uses all mechanical relays for high current switching. This will be considered “Revision 4” of the schematic from this point forward. Any revisions to this version that maintains all mechanical relay power switching in the igniter circuit will be signified by using a letter – e.g. Revision 4a.

1) Rerouted ground side of select relay coil through MOSFET (Q1) that senses when ignition signal is present. This modification was made to make the continuity sensing circuit safer and to save battery power.
2) Traded positions of Select Relay and ignition relays on the schematic. This puts the select relay next to ground and segments the drawing more logically.
3) Redesigned continuity circuit arrangement to eliminate short path when pad is selected and insure that the continuity indicator LED’s work properly not matter the position of any switch on the controller. The continuity LED indication will not be active while the ignition switch is depressed.
4) Rerouted all power sources for controller side LED’s to originate for controller side feed instead of pad box circuits for simplicity of wiring.
5) Changed Diode arrangement at key switch (SW4).

4/3/07 – Revision 5a

- This revision removes mechanical relays from the pad specific circuits that are duplicated as multiple pad circuits are added.
- I have now added detailed schematics on the last pages for each circuit board, cables and harnesses. This expands on the simplified schematic and shows interconnections between the sections as net symbols.
- Expandability and practicality of construction has now been considered at length. The organization of the circuit boards takes all indicators and switches off the circuit boards and places them on wiring cables and harnesses, as they will be mounted in a panel. The circuit boards now shown can be used to build a controller that will support any number of launch pads. The only changes that need to be made for a number of launch pads greater (or less) than the four (as I have designed mine for) is to change the switch and indicator assemblies as well as the large connector harnesses and cables. No changes need be made to the circuit boards. You just have to add more pad control boards, as required.
- Note that the main pad circuit board is the “motherboard” of the system and located in the pad side box.
- I have added a schematic showing 2 pad circuits built on the same circuit board. After some consideration, I feel that this is the best way to build the pad circuits from a monetary and expandability standpoint. This allows for simple expansion in pairs. One could start with a simple 2 pad system then later expand it to as many pads as needed by simply adding addition pad cards and changing wire harnesses.

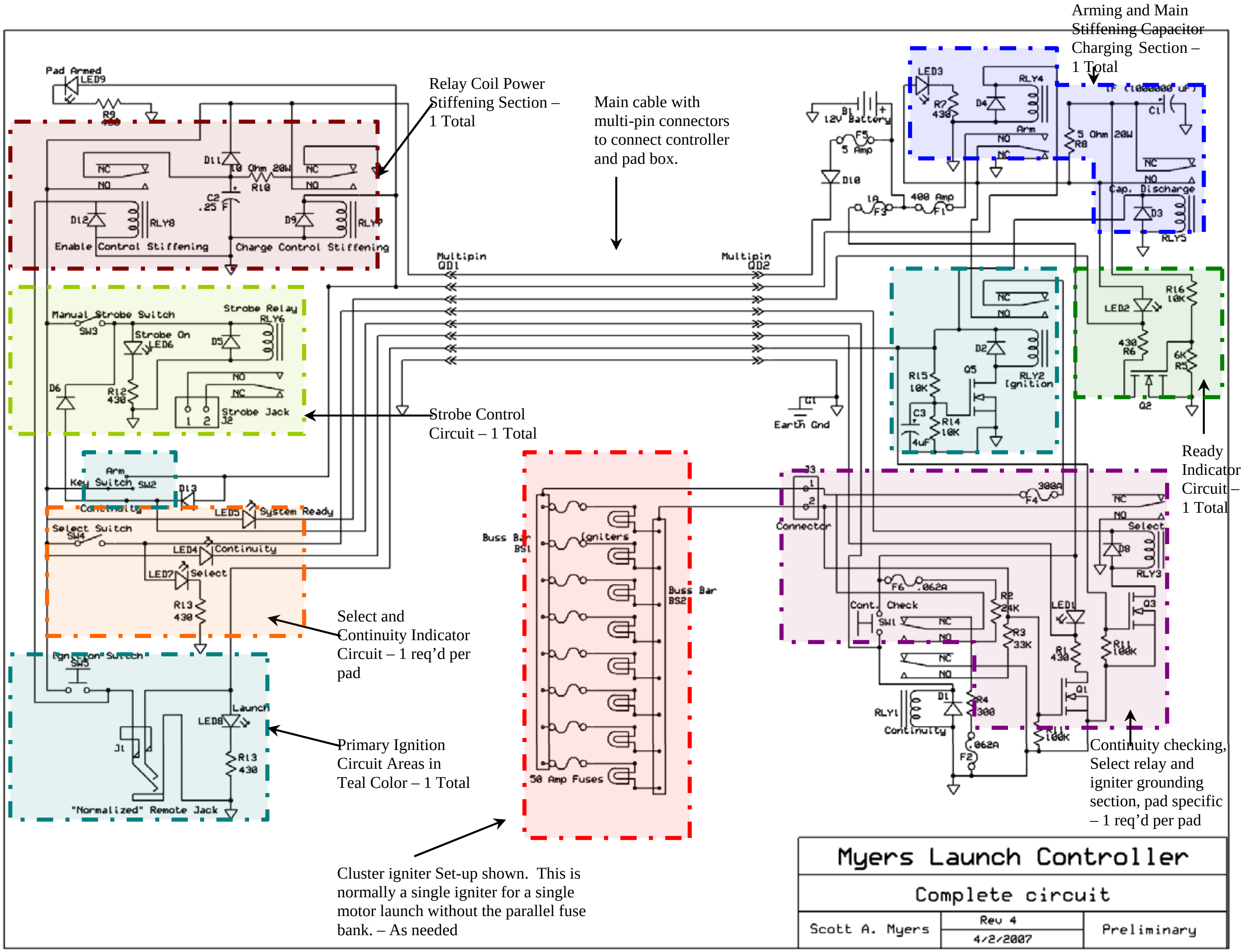
1) I have added a version of the schematic that uses JFET’s & MOSFET’s for the continuity checking and the select relay functions. This is the circuitry type that my final build will use. This schematic version will be considered “Revision 5*” of the schematic from this point forward. Any revisions to this version that uses MOSFET power switching in the igniter circuit will be signified by using a letter – e.g. Revision 5a. This MOSFET power switching circuit for continuity and select functions arrangement allows for the following:
    a) Improves expandability and modularity of the circuit. With this arrangement, additional pads can easily be added to the pad side circuits through the use of additional daughter boards. Since the JFET & MOSFET devices are small in size this allows the daughter boards to be small and lightweight since it contains no mechanical relays.
    b) Reduces size if the pad box; especially for high pad count controllers. On a controller system that has more than 1 pad control board, the number of mechanical relays can get very high in my design. Since mechanical relays add significantly to the size, weight and current drain of the pad box, eliminating the relays assigned to specific pads can reduce these requirements considerably.
    c) Allows for more cost reducing measures. Since my controller design is intended to be able to handle the very heavy loads of large cluster launches, it should also be possible to make just one or two of the pad circuits designed for this type of load while the remainder are designed for single igniter launches. The select MOSFET’s can be downsized to a single 75 amp or less unit for single igniter circuits while we can use (4) 75 amp or higher MOSFET’s in parallel for the heavy cluster circuits, as shown.
2) Added connector for Battery.
3) Completly reorganized connector wiring.
4) Various Fuse Changes.
    a) Changed main power fuse to an 80 amp slow blow automotive fuse. This will handle 480 amps for 1 second, 280 amps for 2 seconds, or 160 amps for 60 seconds.
    b) Changed F4, F10 & F13 to 20 amp slow blow automotive fuses.

5) Changed C2 to 47000 uF for cost reasons. This will still allow for approximately 1.5 second of stiffening voltage with a 1 amp draw from the control circuit.
6) Added connector for earth ground.
7) Added Quad LED flasher circuit. This alternately flashes two LED’s when the pad is armed. When the stiffening capacitors have then reached full charge, two more LED’s will come on flashing to the same alternating beat as the first two. This signifies that everything is ready to go for launch. If this doesn’t get your attention when at the controller, I don’t know what will!

NOTE: The item numbers and part number descriptions are still far from being complete or correct. The item numbers are now poorly sequenced due to the large number of changes I have made. Not all part descriptions are complete, as it takes considerable time to research individual components.

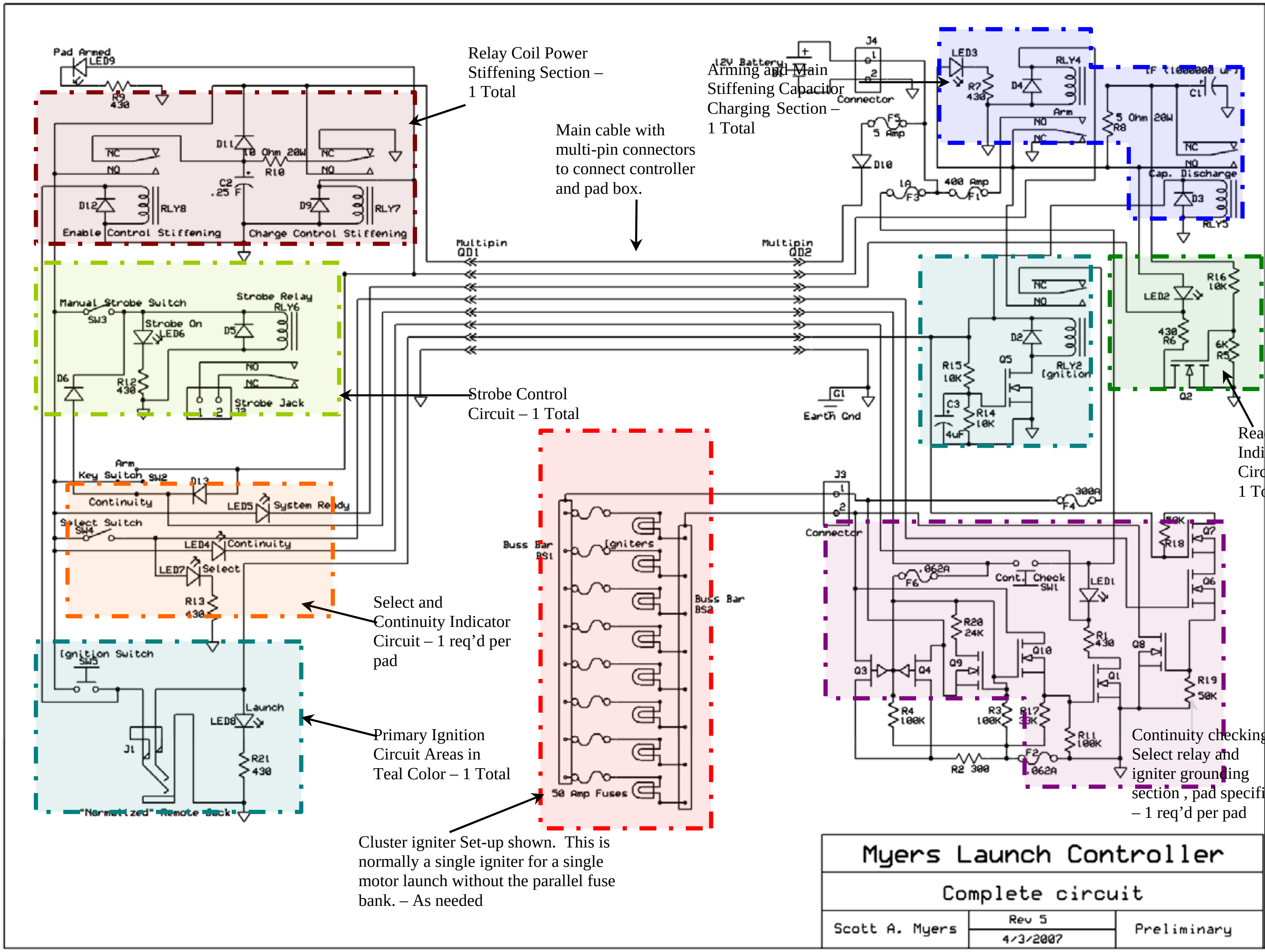
Myers launch controller –REVISION 5a

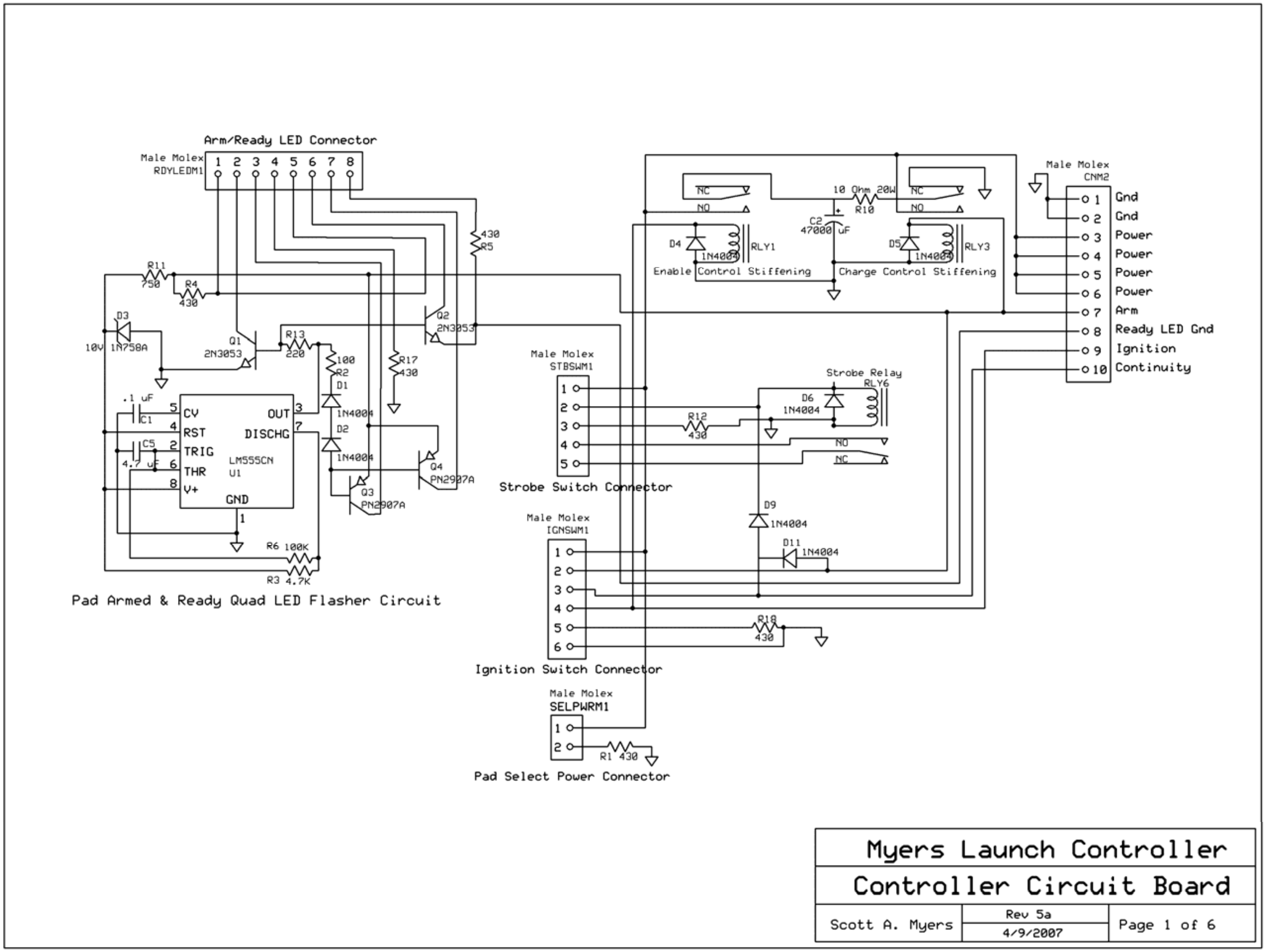
By Scott Myers 4/9/07



Myers launch controller –REVISION 5a

By Scott Myers 4/9/07




Arm/Ready LED Connector
Male Molex
RDYLEDM1
Pad Armed & Ready Quad LED Flasher Circuit
LM555CN
U1
CV
RST
TRIG
THR
V+
GND
OUT
DISCHG
Male Molex
STBSWM1
Strobe Switch Connector
Male Molex
IGNSWM1
Ignition Switch Connector
Male Molex
SELPWRM1
Pad Select Power Connector
Enable Control Stiffening
Charge Control Stiffening
Strobe Relay
Male Molex
CNM2
Gnd
Gnd
Power
Power
Power
Power
Arm
Ready LED Gnd
Ignition
Continuity
Myers Launch Controller
Controller Circuit Board
Scott A. Myers
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4/9/2007
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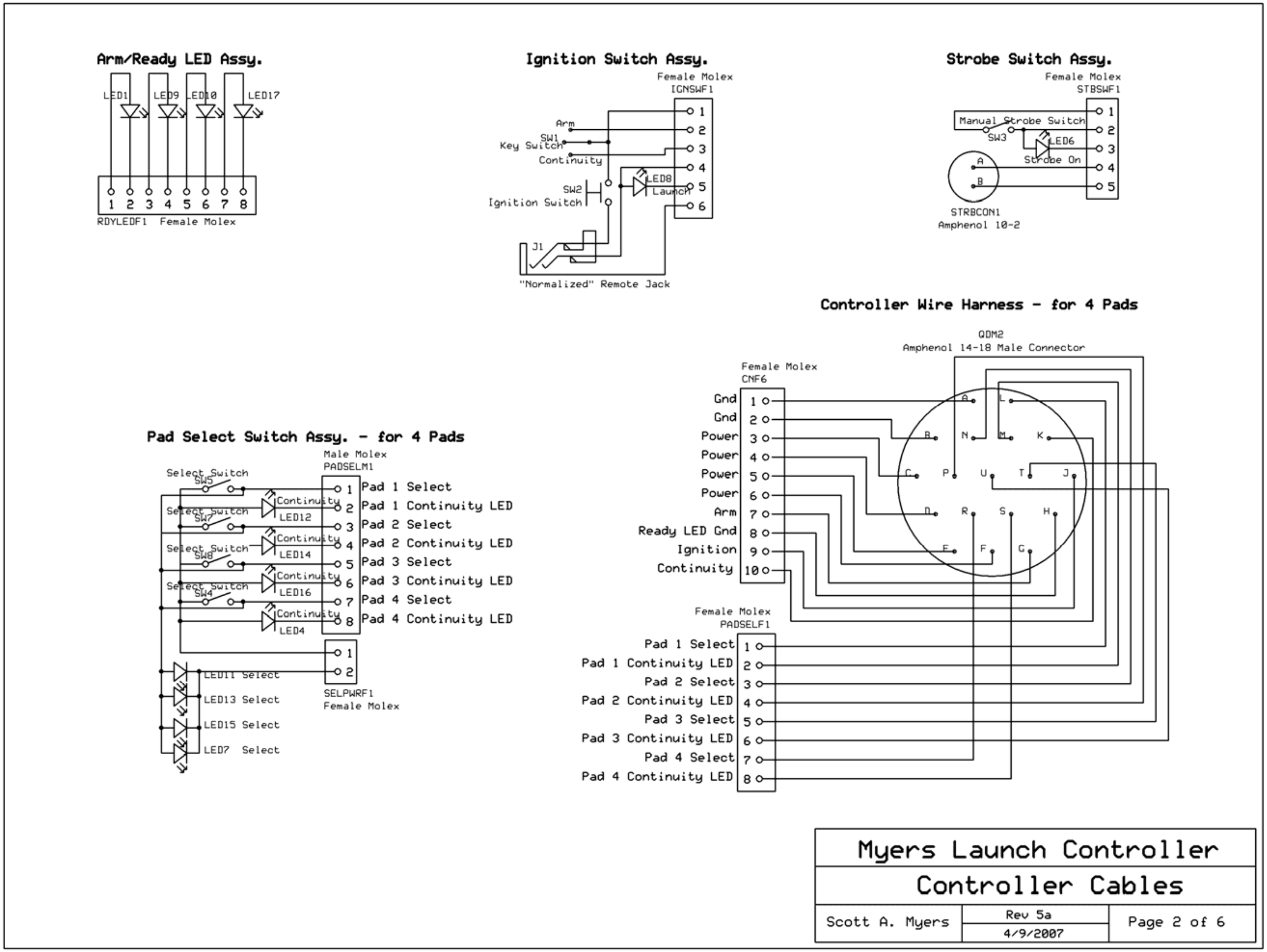

Arm/Ready LED Assy.
LED1
LED9
LED10
LED17
1 2 3 4 5 6 7 8
RDYLEDF1 Female Molex
Ignition Switch Assy.
Female Molex
IGNSWF1
Arm
SW1
Key Switch
Continuity
SW2
Ignition Switch
LED8
Launch
J1
"Normalized" Remote Jack
Strobe Switch Assy.
Female Molex
STBSWF1
Manual Strobe Switch
SW3
LED6
Strobe On
STRBCON1
Amphenol 10-2
Controller Wire Harness - for 4 Pads
QDM2
Amphenol 14-18 Male Connector
Female Molex
CNF6
Gnd
Gnd
Power
Power
Power
Power
Arm
Ready LED Gnd
Ignition
Continuity
Female Molex
PADSELF1
Pad 1 Select
Pad 1 Continuity LED
Pad 2 Select
Pad 2 Continuity LED
Pad 3 Select
Pad 3 Continuity LED
Pad 4 Select
Pad 4 Continuity LED
Pad Select Switch Assy. - for 4 Pads
Male Molex
PADSELM1
Select Switch
SW5
SW7
SW8
SW4
Continuity
LED12
LED14
LED16
LED4
Pad 1 Select
Pad 1 Continuity LED
Pad 2 Select
Pad 2 Continuity LED
Pad 3 Select
Pad 3 Continuity LED
Pad 4 Select
Pad 4 Continuity LED
LED11 Select
LED13 Select
LED15 Select
LED7 Select
SELPWRF1
Female Molex
Myers Launch Controller
Controller Cables
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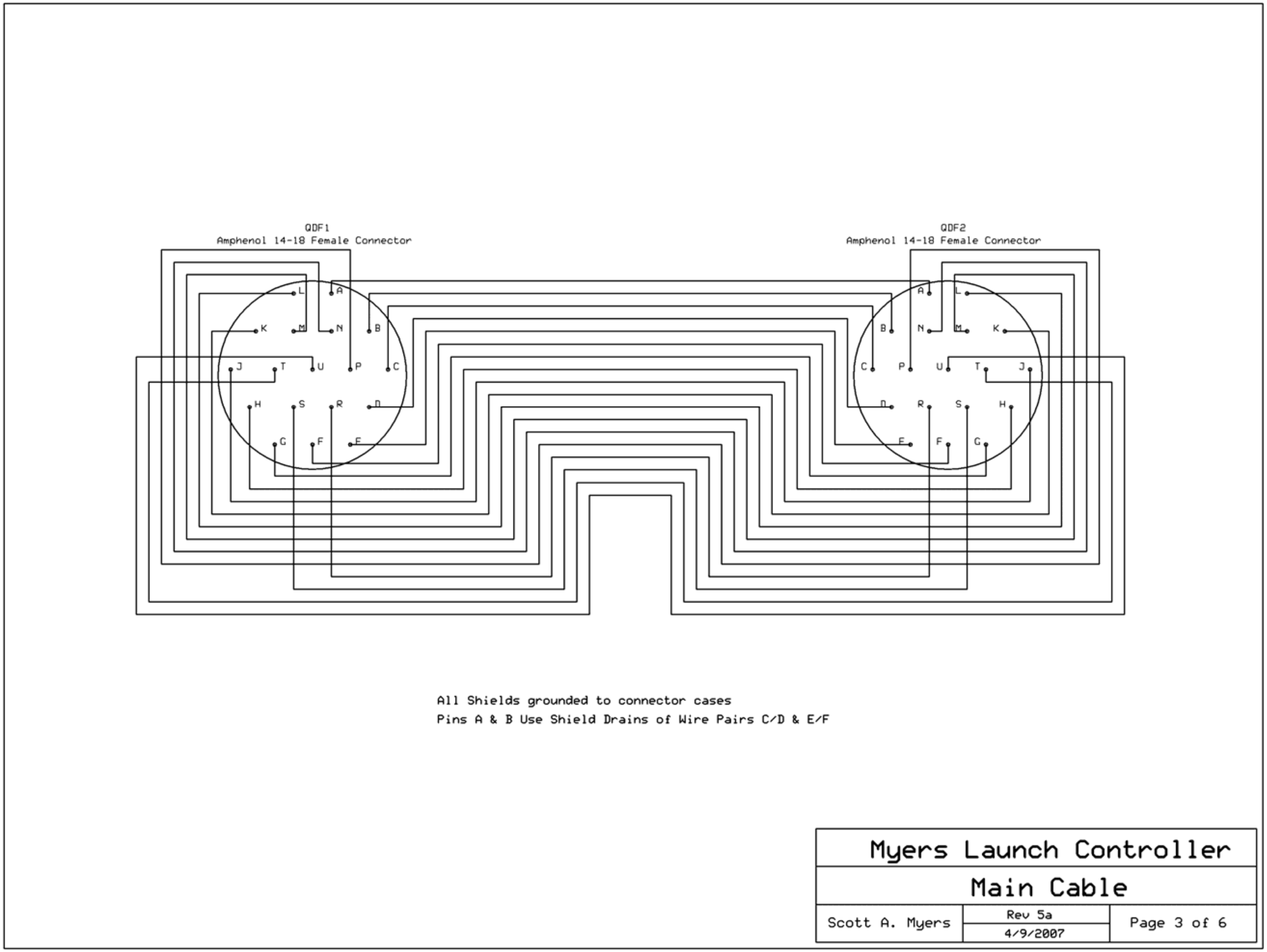
QDF1
Amphenol 14-18 Female Connector
QDF2
Amphenol 14-18 Female Connector
L
A
K
M
N
B
J
T
U
P
C
H
S
R
D
G
F
E
All Shields grounded to connector cases
Pins A & B Use Shield Drains of Wire Pairs C/D & E/F
Myers Launch Controller
Main Cable
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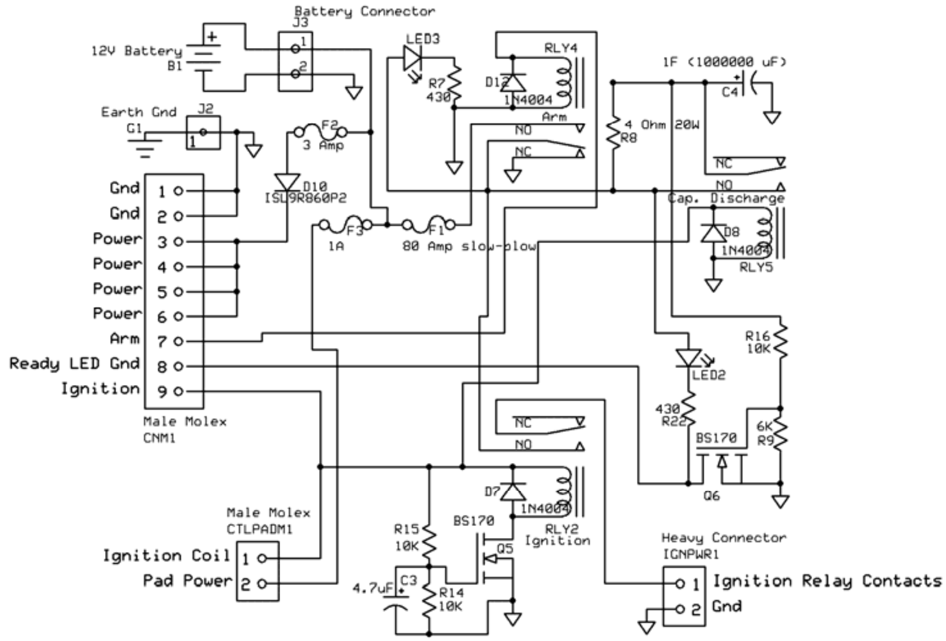

Myers Launch Controller		
Main Pad Circuit Board		
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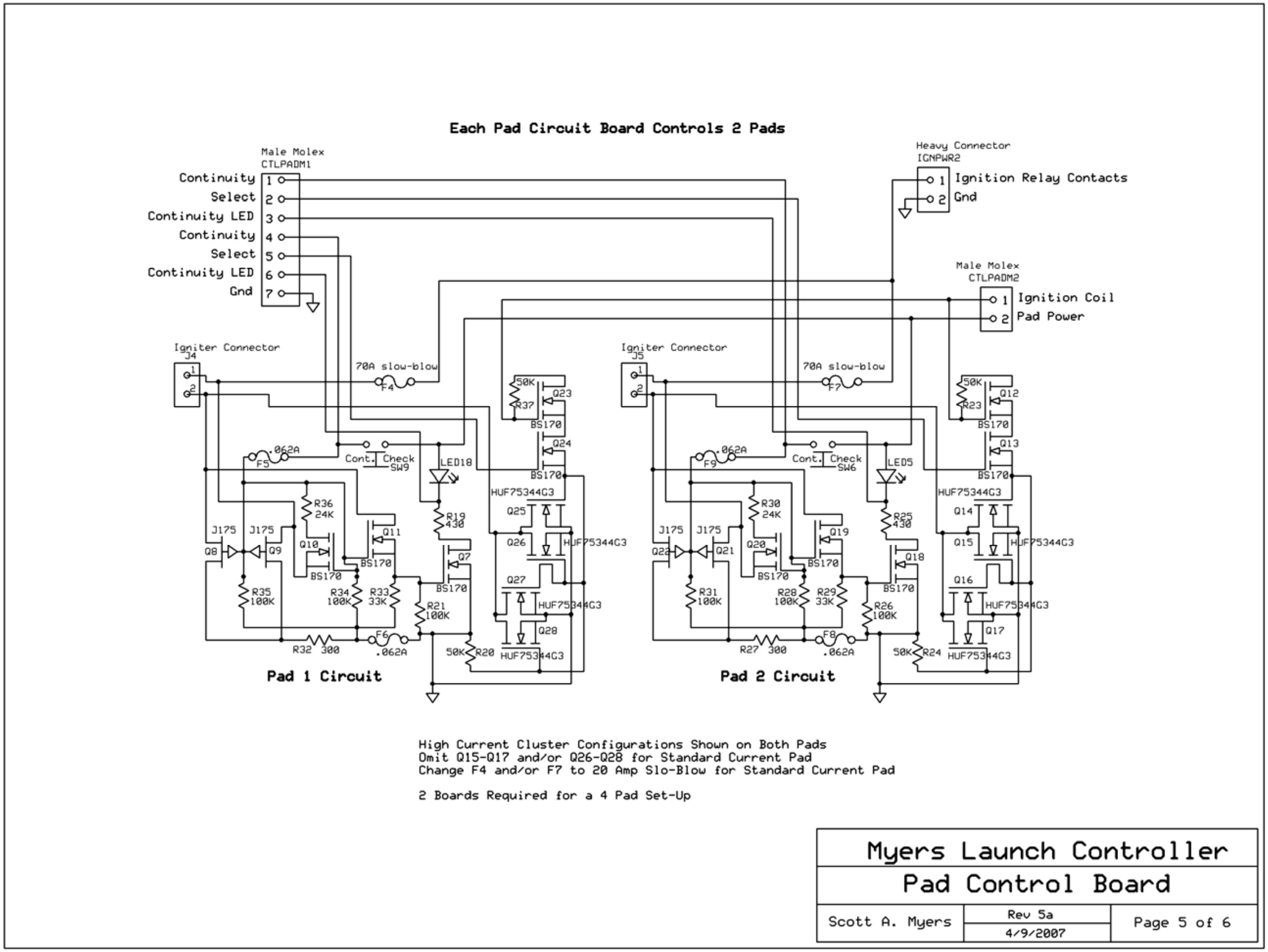

Each Pad Circuit Board Controls 2 Pads
Male Molex
CTLPADM1
Continuity
Select
Continuity LED
Continuity
Select
Continuity LED
Gnd
Heavy Connector
IGNPWR2
Ignition Relay Contacts
Gnd
Male Molex
CTLPADM2
Ignition Coil
Pad Power
Igniter Connector
J4
Igniter Connector
J5
70A slow-blow
F4
70A slow-blow
F7
.062A
F5
.062A
F9
Cont. Check
SW9
Cont. Check
SW6
LED18
LED5
R19
430
R25
430
R36
24K
R30
24K
J175
Q8
Q9
Q22
Q21
Q10
Q11
Q20
Q19
BS170
Q7
Q18
R35
100K
R31
100K
R34
100K
R33
33K
R28
100K
R29
33K
R21
100K
R26
100K
R32 300
R27 300
F6
.062A
F8
.062A
50K
R20
R24
50K
R37
R23
Q23
Q24
Q12
Q13
HUF75344G3
Q25
Q26
Q27
Q28
Q14
Q15
Q16
Q17
Pad 1 Circuit
Pad 2 Circuit
High Current Cluster Configurations Shown on Both Pads
Omit Q15-Q17 and/or Q26-Q28 for Standard Current Pad
Change F4 and/or F7 to 20 Amp Slo-Blow for Standard Current Pad
2 Boards Required for a 4 Pad Set-Up
Myers Launch Controller
Pad Control Board
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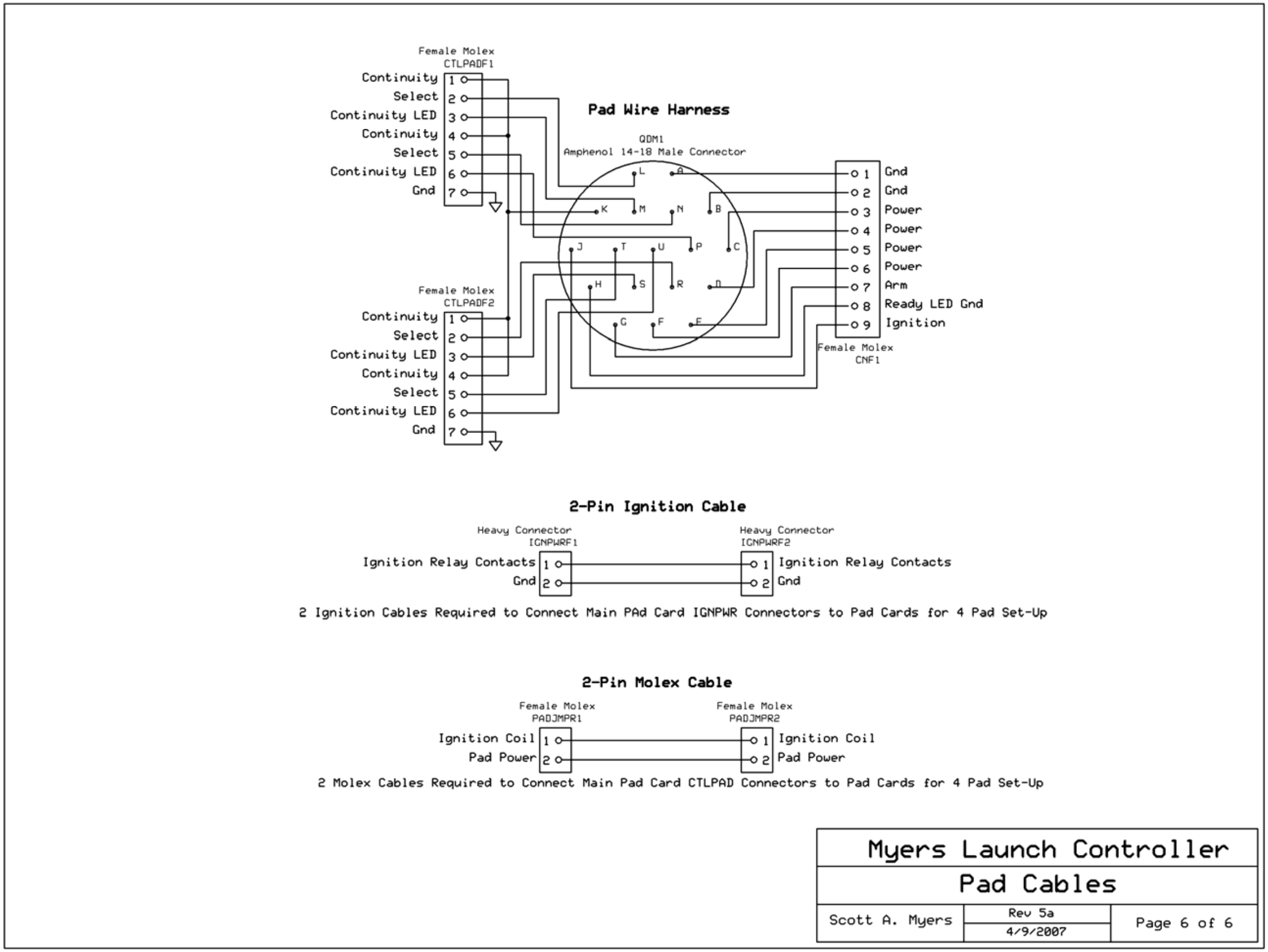
Pad Wire Harness
Female Molex
CTLPADF1
Continuity
Select
Continuity LED
Continuity
Select
Continuity LED
Gnd
QDM1
Amphenol 14-18 Male Connector
Gnd
Gnd
Power
Power
Power
Power
Arm
Ready LED Gnd
Ignition
Female Molex
CNF1
Female Molex
CTLPADF2
Continuity
Select
Continuity LED
Continuity
Select
Continuity LED
Gnd
2-Pin Ignition Cable
Heavy Connector
IGNPWRF1
Heavy Connector
IGNPWRF2
Ignition Relay Contacts
Gnd
Ignition Relay Contacts
Gnd
2 Ignition Cables Required to Connect Main PAd Card IGNPWR Connectors to Pad Cards for 4 Pad Set-Up
2-Pin Molex Cable
Female Molex
PADJMPR1
Female Molex
PADJMPR2
Ignition Coil
Pad Power
Ignition Coil
Pad Power
2 Molex Cables Required to Connect Main Pad Card CTLPAD Connectors to Pad Cards for 4 Pad Set-Up
Myers Launch Controller
Pad Cables
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