From: **Steffen POSA** steffen.posa@radiall.com
Subject: Radiall Switch (mod/hack) for cryo
Date: July 5, 2018 at 10:57 AM
To: achou@fnal.gov

FYI-

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---------- Forwarded message ---------
From: **Reed THOMAS** <reed.thomas@radiall.com>
Date: Thu, Jul 5, 2018 at 11:51 AM
Subject: Fwd: DC Voltages on your coaxial switches
To: Steffen POSA <steffen.posa@radiall.com>

Steffen,

Here is the article I mentioned on the phone. It is able to be distributed outside of Radiall. As you know Radiall makes no claims in the cryo temperatures, however, I have many contacts that will attest to the switches working down in the mK range.

Reed

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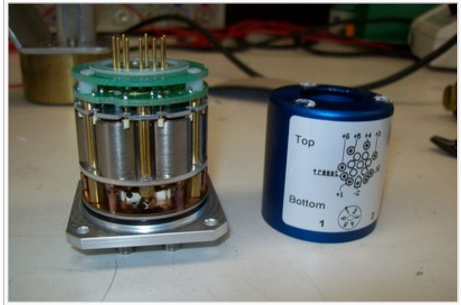
Switch Modification and Installation

Let us begin with the 6 port Radiall R573423600 switch. The data sheet shows the out of the box version of the switch and includes a circuit diagram for easy operation. It is probably not a bad idea to test the switch to see if it is working at this point, before any modification has taken place. A voltage of 28 V and a current between 150mA (for individual sets) and 750 mA (for group reset) is required. Don't forgot that there are no protection diodes in the circuit and one should be used if manually operating the switch to prevent dangerous voltage build up over the inductors. If everything seems to be working you can proceed with the modification.

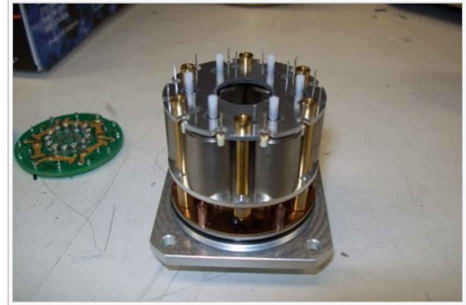
Modification

The first step of this modification process is to remove the blue outer casing. To do this one must first break the epoxy on the 3 screws keeping it secured. After this is done the screws and cover can be removed revealing inside of the switch. The next step is to remove the circuit boards. The circuit boards are only connected to the rest of the switch via push pin connectors so they can be removed without breaking anything if done carefully. The top board should be removed first as it is easier to remove and the pins are relatively sturdy. be sure to save the screws and plastic spacers for use later. The second board is tricky because it requires a significant amount of force but one must be careful not to break the solenoid pins which are extremely fragile. The solenoid pins are held in place with plastic and this plastic may be broken in the removal process. Breaking one of these plastic anchors is ok as long as the wires which electrically connect the pin to the solenoid remain intact but it should be avoided. Now it is a good idea to somehow reinforce the solenoid pins. This can be done by applying a small amount of epoxy to the base of each pin, however take care not to let epoxy get inside the solenoid as this can impede the movement of the pins and render the channel inoperable.

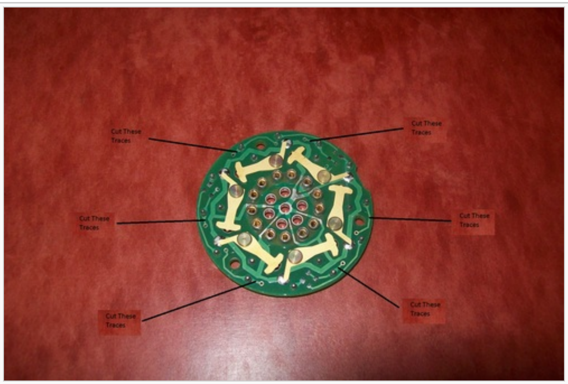
Unmodified Radiall switch

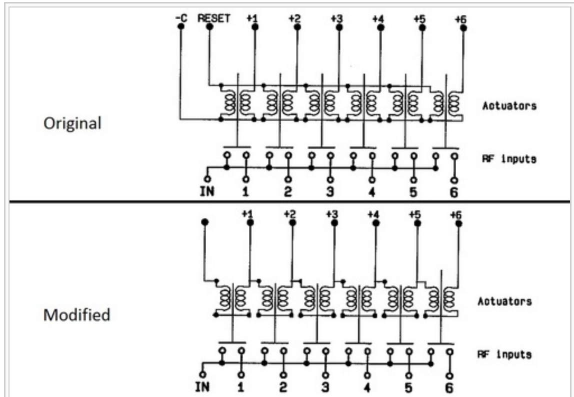


Unmodified switch with cover removed


Switch with exposed solenoid pins

The inner circuit board connects to both the solenoid pins and the upper circuit boards with the pushpin receptacles that tend to fail at low temperatures. an image of this circuit board can be seen below. Note the connections in the board. There are 13 pins in circle in the center which are connected to all 3 pins on each cylinder which makes 18 total solenoid pins. The center pins consist of a common ground and a set and reset pin for each cylinder making 13 total. We can still use this board, but we need to remove (desolder) the female push pin connectors and instead directly solder connections into the remaining via's. Now the bias scheme we use relies on sending current from the set pin to the reset pin in series. This allows the same magnetic field to be applied with half the current, with a reset being accomplished by reversing the direction of current in the circuit. In order for this to work the common ground connection must be broken between the various solenoids. In the first revision we just cut the PCB traces between various common pins on the circuit board. A circuit diagram of the change can be seen below, however this circuit diagram includes all the circuit boards not just the inner one, and In our case the set and reset leads will be tied together on a higher level circuit board.


Inner circuit board



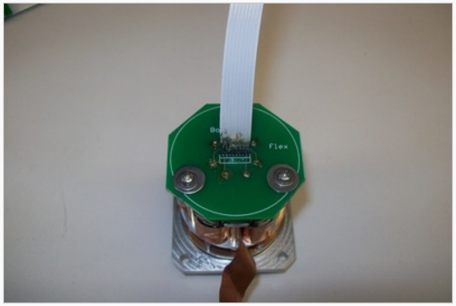
Before and after circuit diagram for setting and resetting pins

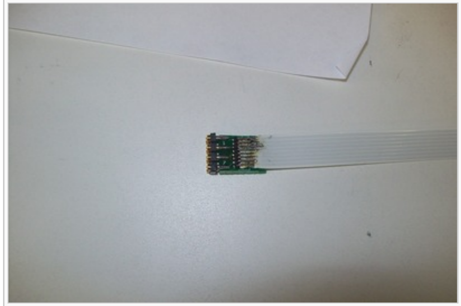
We also removed the pushpin connectors from the 13 inner pins, and soldered wires directly into the holes. These wires were then soldered into an upper board designed to rout current pulses to the various cylinders. This soldering procedure depends on which circuit board version you are using. In the first iteration there are only 7 holes on the upper cirucit board. In the second version there are 12 holes on the upper cirucit board.

Board1: Going counter clockwise with the pin to the right of the common ground being 1 the circuit boards are connected such that lower pin (LP) 1 goes to upper pin (UP) 1, LP 2 and 3 go to UP 2, LP 4 and 5 go to UP 3, LP 6 and 7 go to UP 4, LP 8 and 9 go to UP 5, LP 10 and 11 go to UP 6, and LP 12 goes to UP 7. The common ground pin is not connected.

Board 2: This is simipler in that each hole, except the common ground, is directly connected to the hole above it, and the necessary pins are connected inside the cricuit board.

This upper circuit board routes 7 outer pins to 8 inner pins in a line, although the 8th pin is not connected, designed for one of the Sullins 1mm connectors. This connector then connects to the copper flex cable which goes to the connector PCB's. The complete modified switch can be seen in the images below.


Modified switch with copper flex connector


Connection PCB between switch and break out board

Note there is some damage to the copper flex cable. The plastic insulation on these is sensitive and care should be taken when soldering them to the Sullins connectors. I recommend using solder paste and a very fine tip soldering iron in the future.

Lastly there is a change to the orientation of the ports on the front of the switch do to the numbering convention of Radiall vs our control electronics. There are two circuit boards on top of the switch. As far as I can tell the bare switch with no circuit boards is symmetric. Any orientation of the port numbers is set by the orientation of the first circuit board. The orientation of all the following electronics is then set by the location of the common ground on that first circuit board. Everything after that should only be able to fit together in the way that makes sense all the way up to the control electronics at room temperature. The only subtlety is that the ribbon cable connections must be soldered into the correctly numbered holes.

If you keep the bottom circuit board in its initial orientation then the numbering for the cylinders on the front goes as follows. Starting from the dimple in the front face and going clockwise:

- port 6 (next to the dimple)
- port 1
- port 2
- port 3
- port 4
- port 5

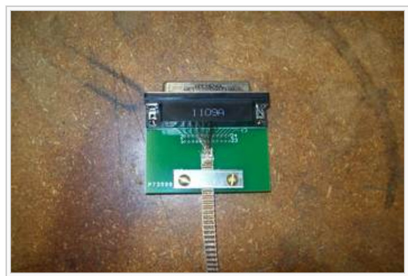
This is only if the bottom circuit board is kept in its initial orientation. In addition there is a notch on the bottom circuit board that roughly aligns with port 6.

Installation

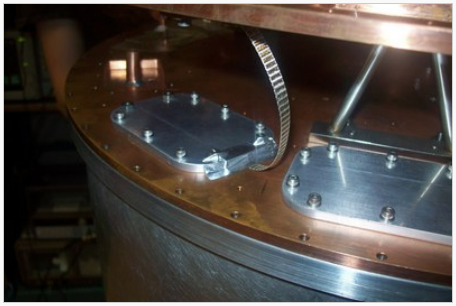
The system for Biasing the switch while inside the DR starts at room temperature with the cold SMA control board. The board is battery powered and controls the switches via a 25 pin Dsub output which is divided into 3 groups of 7 control pins. With this setup the board can independently control 3 switches. Pulses can be sent using either the manual controls on the front of the box or with a computer via a serial port. The control box connects to a room temperature vacuum port in the top of the fridge with a female to female Dsub 25 pin cable. This port has another 25 pin connector should more connections be desired. Inside the vacuum connector is a connector circuit board which routes the Dsub 25 to a 24 pin NbTi? woven loom ribbon cable, with the larger holes used to screw on a clamp pcb to provide strain relief for the ribbon cable. The ribbon cable was obtained from CMR-Direct and the connectors were assembled by hand.


Room temperature control box


Room temperature vacuum port


Dsub connector PCB

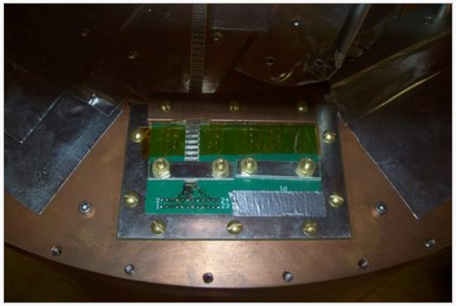
The ribbon cable continues from room temperature all the way to 25 mK. The outer insulation for the NbTi? cables can be stripped easily from these wires with a pair of edged tweezers pictured below. Care must be taken to heat sink the cable at every stage and to prevent stray light from higher stages getting through to lower stages. In our DR the heat sinking was done with copper bar stock from McMaster? Carr and the ports were port covers were modified to allow a small channel through the side of the port for the ribbon cable to enter. The sides of these caps were then taped over with aluminum tape to prevent as much stray light as possible. Both of these precautions can be seen below.

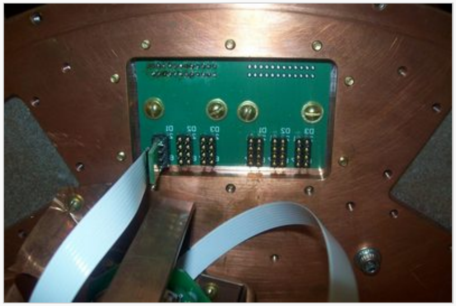

Ribbon cable entering modified port


Channel for ribbon cable is milled in bottom of port cover

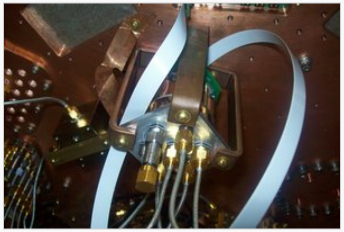

Tweezers for stripping NbTi? insulation

At 25 mK the ribbon cable connects to a light tight PCB which routes the 24 pins of the ribbon cable to 3 8-pin samtek male connectors. The board has 2 copies of these connections so 2 ribbon cables are connected to 6 total 8-pin connectors. The modified microwave switch can then book connected directly to these 8 pin connectors. Note in the images below the solder pins of the samtek connectors have been clipped and taped over with Kapton tape. This is a precaution to protect the ribbon cable from sharp edges that might damage it.

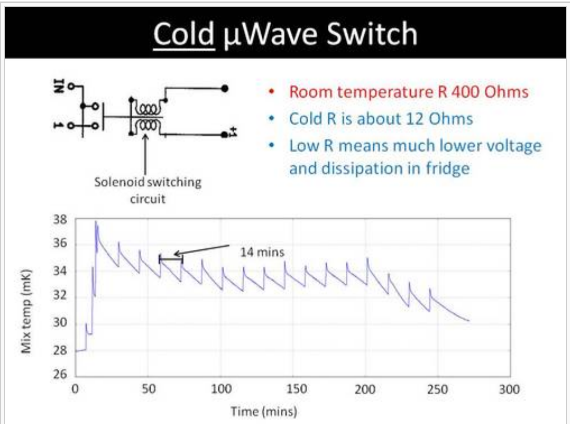

20 mK board above


20 mK board below

Lastly the switch is mounted vertically to the mix plate using left over copper bar stock. This can be seen in the image below which shows how the switch has been wired into several experiments at once.


Mounted cold SMA switch

Part of the reason this switch can be used effectively at low temperature is that the resistance inside the solenoid decreases dramatically at lower temperatures. At room temperature the resistance for one of the solenoids to ground is about 200 ohms. With our modification of the circuit we put two solenoids in series and the resistance is around 400 ohms. At low temperatures the series resistance is about 10-12 ohms. This means much less voltage can be used to drive the same current through the circuit and the dissipation at low temperatures is much less. This is in the picture below which shows a temperature vs time plot, where the switch is being used every 15 minutes or so.



Circuit Diagram and Temp vs Time plot

-- TedWhite - 16 Aug 2011

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Topic revision: r9 - 27 Apr 2012 - 20:10:49 - TedWhite