Application Information for the Two Terminal Switch™

by Doug McNutt
Smith Research and Technology, Inc.

General

The Two Terminal Switch by SRT is intended to be the ultimate in simplicity. When current flows through the 1/2 inch diameter hole the switch closes and that's all there is to it. The switch derives all power required for operation from the current being measured so there is no off-state leakage in the switched circuit and there is no minimum on-state voltage required to keep things working inside. Because there is no electrical contact to the insulated wire carrying the sensed current the isolation between input and output is perfect.

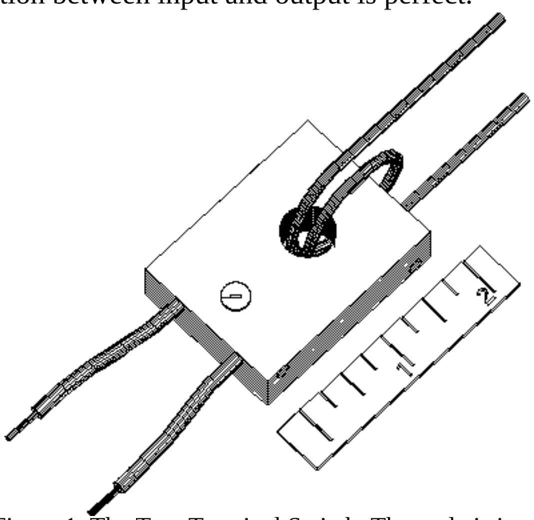

Figure 1. The Two Terminal Switch. The scale is in inches. Two turns are shown for the sensed conductor.

Of course the above is an oversimplification. What follows is intended to identify the limits of the simplification and provide guidelines and ideas for users of this unique switch.

Input

Current is measured in the Two Terminal Switch with a magnetic circuit which surrounds the hole. Alternating current flowing through the hole creates a magnetic field in a ferromagnetic material. The changing magnetic field then induces a voltage in a secondary winding which is rectified and further processed into a form which operates the switch.

You can think of the sensor as if it were a current transformer, but it is not. The output is a voltage, not a current, and the magnetic material is formed so that it will not saturate even under overloaded conditions. DC current at least up to the amplitude of the AC specified for each switch is allowed. Of course the switch will not respond to the DC but its presence will not affect the trip setting.

Sensitivity of the switch is specified in terms of the total current flowing through the hole. If a conductor is passed repeatedly through the hole by looping the current seen by the sensor is the current in the wire multiplied by the number of passes through the hole. There is a small variation of sensitivity with the position of the conductor within the hole. Maximum sensitivity occurs when the conductor is furthest from the switch wires. Real current transformers exhibit less of this effect, but they are easily saturated. When using multiple turns it is best to coil the turns on the short end away from the switched wires. Figure 2. If stability of the switch point is critical it is best to secure the conductor so that it cannot move within the hole.

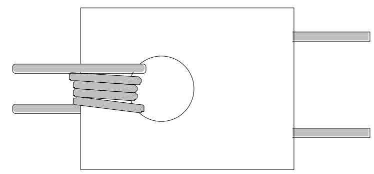

Figure 2. Best way to wrap turns on the Two Terminal Switch

Most users will find that the factory set, non-adjustable version of the Two Terminal Switch is the least expensive and most reliable model. Nobody will change the setting of a control that isn't there. By choosing a relatively high value of the switching current users can achieve some adjustment by adjusting the number of turns they place in the hole. For example if a switch setting of one ampere is desired and a 4 amp switch is ordered then 3 turns will switch at 1.33 amps, 4 turns at 1.0 amp, and 5 turns at 0.8 amps.

The input device depends on magnetic induction and thus on the rate of change of current. It thus has a frequency response such that the trip current decreases with increasing frequency; the device becomes more sensitive. The increase persists through a few kilohertz and then subsides. For sensed currents with high harmonic content the sensitivity of the switch may be higher (lower trip point) than that specified for sine waves.

Internals

The switching time constant depends on several things. Note that it is meaningless to discuss switching times less than a period of the alternating current. Such fast times would amount to a saturating amplifier which produces a square wave at the line frequency, not a switch. Internally, the output of the sensor is rectified and filtered to produce a DC voltage. The DC level depends on the average value of the current over a history of 10 or so cycles. In the case of a current which stays just below the trip point for a long time the switch will respond quickly to a small change because the filter capacitor is charged almost to the critical DC level. If the current rises suddenly from zero to the trip setting it will take longer to charge the capacitor. If the current suddenly rises well over the trip setting the resulting high voltage output from the sensor will charge the capacitor quickly. As a general rule you should allow 3 or 4 cycles of the line frequency for the switch to operate. The very sensitive switches, less than 1.5 amperes, are slower.

Switches should have hysteresis. That is they should operate at a higher trip point with increasing current than on the way down. If there is no hysteresis it is possible that noise in the sensed current could cause a rapid on-off fluctuation in the switch. That is bad for both the switch and the connected load. Internal circuitry in the Two Terminal Switch is designed to provide about 20 percent hysteresis in standard models. More or less can be provided on special order. The switches are specified at the trip value with rising current.

The trip point is set internally with a zener diode. There are thermal changes in the breakover voltage of the zener, in the resistance of the copper secondary, and in the magnetic material. An effort has been made to balance these changes to minimize the change of trip point with temperature.

Output

The output circuit is a pair of power metal oxide field effect transistors, MOSFETs, connected in series source to source. Figure 3. One drain is connected to each output wire. Internal to each MOSFET is a diode which conducts in the forward direction when the MOSFET is reverse biased. From a user's perspective the equivalent output circuit is a silicon diode in series with a small resistor for either polarity. The resistor is the drain-source on resistance of one of the MOSFETs and the diode exhibits a thermal voltage which can be taken as 0.6 volts regardless of current.

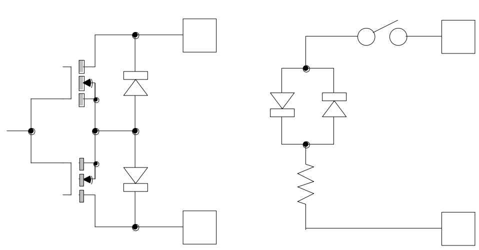

Figure 3. The output components of the Two Terminal Switch and the equivalent circuit.

Note that this configuration does not depend on zero crossings in the output load as does a triac. DC switching is possible and phase shifts between current and voltage are not a concern.

The main limitation to the loading of the switch in the on state is heating of the MOSFETs, but there is an instantaneous current limit. Empirically we have determined, for sine waves, that the power dissipation in the MOSFETs is very nearly the product of root mean square (RMS) voltage across the closed switch and the RMS current. The minimum RMS voltage is about 0.4 volts because of the diodes. In an ambient atmosphere at 25°C with no air movement the dissipation limit is 6 watts at which the rise in temperature will be about 60°C. Much of the heat is carried off by the copper in the switched wires which are connected directly to the drains of the MOSFETs. Forced air cooling will improve the dissipation.

A wide selection of MOSFETs is available on the market and the characteristics improve daily. At this writing 1000 volt units are available with on resistance of less than 10 ohms. 60 volt units are available with resistance of tens of milliohms. With careful choice of MOSFET to match the load 500 watts can be switched.

Depletion mode MOSFETs can be used to prepare a normally on switch but currently available units are not fully on at zero bias. Since this type of switch generates the control voltage for the MOSFETs from the current being measured there is no voltage available to keep them fully on at zero input. There is thus no normally closed switch in the catalog. Sorry.

There is another limit in the on state which is set by the size of the connecting wires within the MOSFET itself. An instantaneous current higher than the fusing current of these wires causes instant failure. The worst gotcha is a tungsten lamp. The resistance of tungsten changes by 40 times between room and operating temperature so startup currents are very high. If you must switch such lamps a small current can be kept present to keep the filaments slightly warm or you can choose a switch rated at 40 times the running current. Other examples of high startup current are capacitor start motors and power supplies with capacitor input filters.

In the off state the switch is limited by the breakdown voltage of the MOSFETs. If exceeded, failure is instantaneous. There is no internal protection against transients such as lightning induced surges. If the load is likely to produce a transient as a result of being switched off, a relay coil for example, you should either select a MOSFET with sufficiently high voltage rating or you should use external circuitry to suppress the transient.

Applications

Figure 4. shows the simplest application. A computer peripheral is automatically turned on whenever the computer is powered up. It has special use when the computer supports software turn-on and turn-off or when it is possible to turn the computer on remotely. The switch should be selected to support the line voltage and the inrush current associated with the peripherals in use. Most modern computer power supplies include inrush limiters.

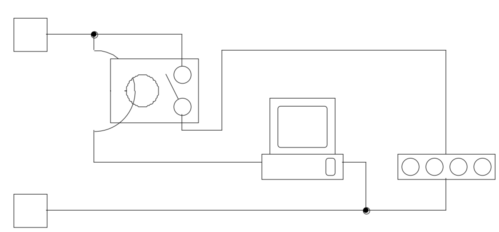

Figure 4. A Two Terminal Switch is used to turn on computer peripherals whenever the computer is powered up.

Figure 5. shows how a Two Terminal Switch can be used to turn on an alternate lamp whenever a primary lamp is off. The circuit senses either failure of the power source or failure of the lamp itself. The secondary lamp can be lighted from the same or an alternate source of power. In this case the current in the relay coil is small but there may be a transient voltage associated with turn-off of the relay. A high voltage, low current switch should be selected.

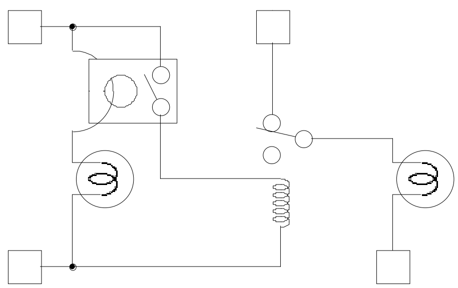

Figure 5. A Two Terminal Switch is used to turn on an alternate in case of failure of a primary lamp or its power source.

Figure 6 shows how the current in a motor can be sensed to indicate a condition of high mechanical load. Motor current increases when the motor is loaded and with some experimentation a Two Terminal Switch can be set up to close when, for instance, the tool in a drill press becomes dull and the corresponding load increases. This circuit could also sense a motorized door attempting to close on an interfering object. With the addition of a relay the circuit can interrupt the motor current. This Figure 2lso shows how a resistive leak across a switch can keep a tungsten filament warm and prevent high inrush current which can damage a switch.

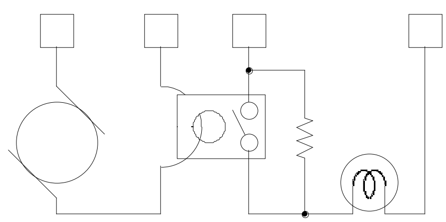

Figure 6. Sensing motor current with a Two Terminal Switch.

Figure 7 shows a high power three phase motor which should be protected from loss of a phase. Such motors can continue to run and appear normal when a phase is lost, but the remaining phase draws excessive current and can destroy the motor. The circuit assumes that a starting relay is already present with a push to start and a push to stop switch. Three Two Terminal Switches which sense the current in each phase are connected in series between the power source and the holding coil of the starting relay. The relay will drop out whenever any phase stops drawing current for numerous reasons including an open connection at the motor terminals. It does not sense an open winding within this delta connected motor; that design modification is left for the reader. The selected switch should support the coil current and be a high voltage version because of switching transients.

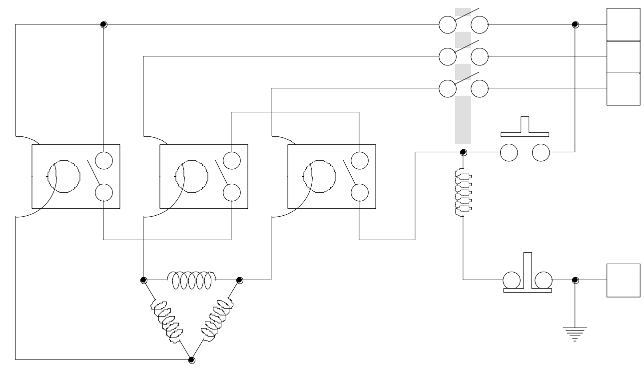

Figure 7. Two Terminal Switches protecting a three phase motor.

When heating elements are used in parallel it is often important to be able to identify a failure which might not be noticed in a system which is thermostatically controlled. Figure 9 shows a way to use Two Terminal Switches for the purpose.

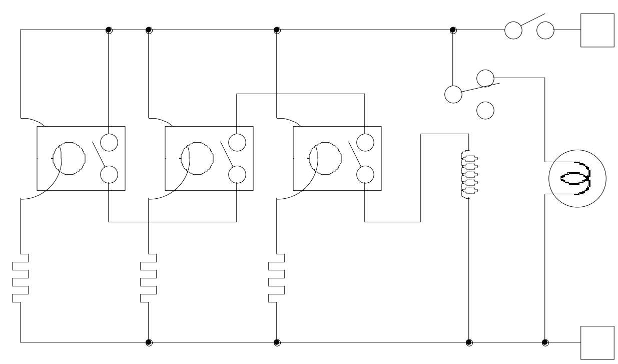

Figure 9. Checking for continuity of heating elements.

Disclaimers and Such

The Two Terminal Switch is available from:

Smith Research & Technology, Inc.
3109 N. Cascade Ave., Bldg. 201/202
Colorado Springs, CO 80907-5190
Voice : 719 634 2259
FAX : 719 634 2601
email: dsmith@srt-inc.com
dmcnutt@macnauchtan.com.

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