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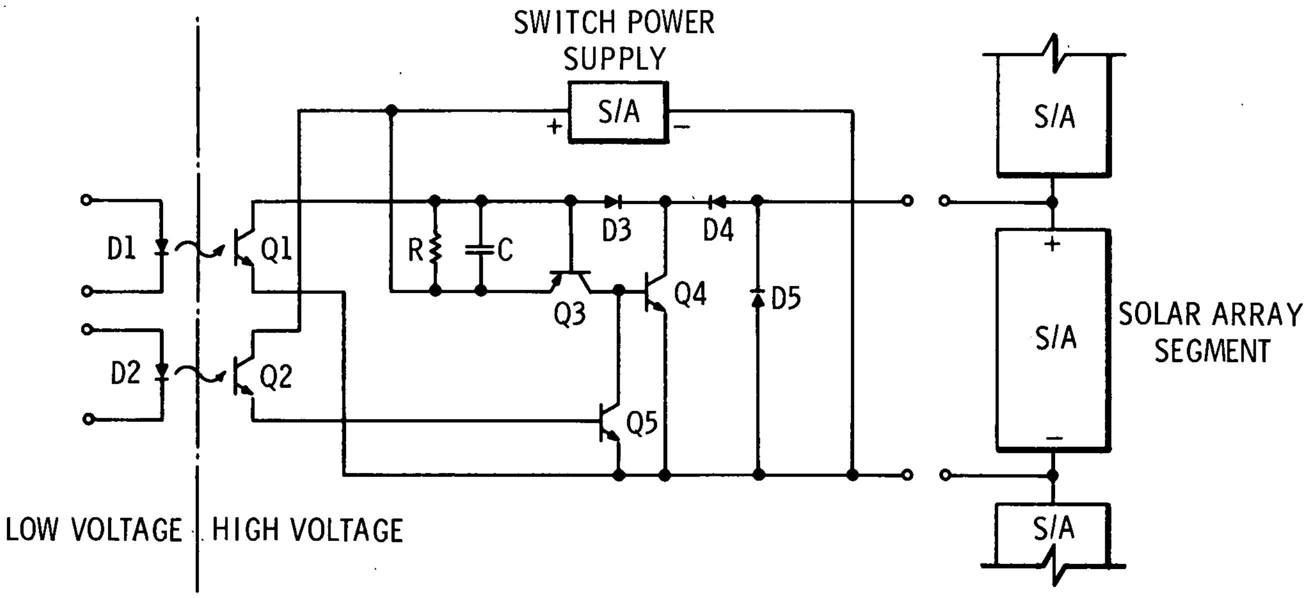
# NASA TECH BRIEF
## *Lewis Research Center*



## Self-Protecting Solid State Isolated Switch




### The Problem:

One of the new concepts in space power systems involves the delivery of regulated power directly from a solar cell array to a load. This approach eliminates the power processer with its attendant losses and offers the potential for a lighter weight, more efficient and more reliable power system. Since the output voltage of a solar array varies with temperature, cell degradation and load current, some means of regulating the array output voltage must be employed. One method of providing this regulation is to short out blocks of solar cells with a switch. If the switch voltage drop is low, the resulting power dissipation is also very low since the shorted cells will be operating near their short circuit point.

Some loads, such as ion thrusters, tend to arc periodically. This causes a short across the solar array supplying that load. During this condition, stored energy can result in large currents flowing through switches which are in the "on" condition. Since the drive to these switches is limited, very high power dissipation could result if they remained in a conductive state.

### The Solution:

A solid state switch having the following capabilities:

1. Hybrid or IC form compatible with direct mounting on the solar array substrate;
2. Self-latching such that a continuous signal is not required to hold it in either the on or off state;
3. Positive switch control by having separate signal lines for on and off control rather than a single line with the first pulse turning the switch on and the second identical pulse turning the switch off;
4. Electrically isolated from input signals so that supplies which float at high potentials (1 kV to 15 kV) can be regulated; and

(continued overleaf)

5. Self-protecting such that current surges which may occur during load transients (such as ion thruster arcs) will not cause switch failure.

## How It's Done:

As shown in the figure, the switch is turned on by providing a current pulse to LED D1. The light output from D1 activates transistor Q1 allowing Q3 to turn on thereby providing base drive to Q4. Once Q4 reaches saturation, the path through D3 provides a latch to hold the switch on.

To turn the switch off, a current pulse is provided to LED D2. The light output from D2 activates Q2 allowing Q5 to turn on. Q5 then shorts out the base drive to Q4 turning the switch off.

The optical path between the LED's D1 and D2 and their respective transistors Q1 and Q2 provides the electrical isolation between the control signals and the rest of the circuit. Other than for diodes D1 and D2, the entire circuit including its power supply floats at the array segment potential. This can be as high as 15 kV for some anticipated loads.

The voltage at which the power supply will operate is the sum of the emitter-base drop of Q3, the drop across D3 and the collector-emitter drop of Q4. By sizing the power supply voltage at the knee of the V-A characteristic to be higher than this voltage summation, the supply will operate in the constant current region. By this means, the power supply can be used to control the base drive current to Q4. During a flight mission, the current output of the switch power supply will degrade due to radiation damage. However, the current capability of the solar array being controlled will also degrade. This allows the ratio of base drive current to the collector current to remain the same over the mission lifetime.

The switch power supply characteristic is used to provide protection for Q4 during transient conditions. As the current through Q4 increases, its $V_{ce}$ will also increase driving the operating voltage of the switch power supply up toward the knee of the curve. As the operating point moves around the knee, the base drive current to Q4 starts to decrease, further increasing $V_{ce}$ of Q4. Eventually the power supply is no longer capable of providing enough voltage to maintain current through the latch leg and Q3 is turned off which in turn shuts off Q4. If the voltage of the switch power supply is sized properly, this turn off will start to occur before Q4 has pulled out of saturation. This prevents the situation from occurring where Q4 could operate for long time periods in a non-saturated condition.

During a flight mission, the voltage of the switch power supply will degrade. The voltage drops $V_{EB}$ of Q3 and $V_D$ of D3 will also vary. This means that the potential difference between the operating region and the knee of the V-A characteristic will vary with time. Therefore, the conditions under which the switch will self protect will also vary. In this particular application that is no problem as long as the switch will remain on carrying its maximum worst case current and turn off if Q4 attempts to pull out of saturation. However, if the degradation were quite severe, it might be necessary to regulate the switch power supply by placing a number of forward biased diodes across it.

The diodes D4 and D5 are used to prevent false turn-on in the switch during solar array transients. If the particular array segment which the switch is across has a somewhat lower $I_{sc}$ than other segments, it will reverse polarity during a short across the entire array. This reverse polarity would turn on the switch through D3 if no other protection were used.

The R and C across the emitter-to-base junction of Q3 are used to put a slight delay in the turn on. This reduces the possibilities of triggering due to noise.

## Notes:

1. The switch power supply is made up of a small number of solar cells connected in series. The current output of a solar cell is a function of its area. Since cells are available in a large range of sizes, the current output of the power supply can be varied over a wide range. The voltage output of a solar cell is a function of the cell resistivity. By using cells of different resistivities and varying the number of cells in series, the output voltage of the supply can also be varied over a wide range. The characteristics of this supply are used to provide a number of functions for the switching circuit.
2. By grouping the solar cells in binary fashion, very fine regulation can be obtained with a few shorting switches.
3. No additional documentation is available. Specific technical questions, however, may be directed to:
   Technology Utilization Officer
   Lewis Research Center
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   Cleveland, Ohio 44135
   Reference: B74-10069

## Patent Status:

Inquiries concerning rights for the commercial use of this invention should be addressed to:

NASA Patent Counsel
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