

📁 Nanosecond SCR Switch for Reliable High Current Pulse Generators and Modulators

Design requirements for modulator and pulse generator circuits include fast rise time, low jitter to enhance short radar or laser ranging applications, low power consumption of the switching components, reliability and stability over operating conditions.

Several new applications for nanosecond SCR switches include automotive collision avoidance systems, laser drivers, photo flash quenching circuits, specially developed circuits for the emerging digital imaging range finders and communication markets.

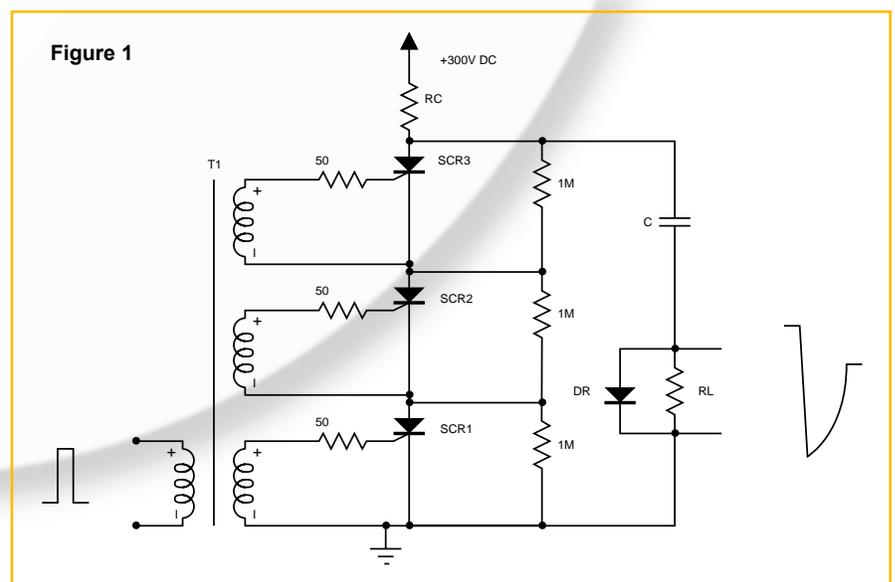
The nanosecond SCR switch (thyristor), allows the designer to upgrade high current, high voltage modulators and pulse generator circuitry. A single device like the military grade metal can GA201A or the commercial grade metal can GA301A, or the soon to be introduced Powermite package UPGA301A are all capable of operating in circuits with supply voltages up to 100 Volts DC and pulsed load current in excess of 50 Amperes. These high-speed thyristor switches can be triggered directly from logic level signals (1 Volt, 200 micro-amps) and all exhibit a rise time of less than 10 nanoseconds to 1 Ampere with only 10 ma of gate drive signal. Single switches operated in this mode can be used as

high current replacements for avalanche transistors, modulators, and harmonic wave form generators.

With minimum circuitry, these devices may be series stacked to provide increased forward blocking capability. A simple application that provides up to 300 Volt forward blocking is illustrated in Figure 1.

Voltage sharing (see figure 1), is accomplished by placing a 1 megohm resistor across the anode-to-cathode of each SCR device in the series string. In practice, the parallel resistor is chosen to equalize the steady-state voltage division. The shunt resistor eliminates the need for tight matching of SCR forward blocking over the operating range.

Capacitor C is charged to 300 Volts through the load resistor RL, (or its equivalent circuit impedance) and DC supply resistor RC. The string of SCRs are triggered on by a pulse applied through the primary of T1. The SCR string turns on if the positive applied pulse to the gate is of sufficient amplitude to trigger the SCR on. At SCR turn-on, capacitor C discharges through the low impedance On-state of the SCR string. This action induces a negative-going current pulse to the load RL. Diode DR across the load is used to quench any parasitic inductive ringing in the circuit from appearing across the load. The value of RC is chosen to insure that anode current to the SCRs is below the holding current, I_H of the string.



This allows the SCR string to reset (revert to the Off-state), and to be ready for the next applied gate pulse.

Figure 2 illustrates an approach that uses a pulse transformer to trigger only part of the string, while the rest of the devices in the string are supplied with gate drive current through the Zener diodes. With a supply voltage of 360 Volts DC, a 95 Volt \pm 5% Zener diode across each SCR in the string prevents unequal voltage distribution. The Zener series resistor should be less than 1 k-ohm to allow Zener voltages to operate in a region above the knee and into the linear dynamic range of the individual Zener diodes. When SCR3 and SCR4 are triggered, 360 Volts appears across SCR1 and SCR2 causing Zener diodes Z1 and Z2 to conduct. Since D1 and D2 are reversed-biased, the current must flow through the gate-to-cathode junctions of SCR1 and SCR2, turning them on. Up to eight stages can be stacked in this manner using a pulse transformer to drive only the bottom two SCRs in the string. Driving three SCRs with a pulse transformer allows stacking sixteen stages, which can switch a 1440 Volt load using a pulse transformer. This application does not require a transformer dielectric isolation rating of more than 300 Volts. Z3 and Z4 are used as transient voltage suppression devices across the lower two SCR's. Z3 and Z4 shunt high voltage or (L di/dt) spikes around the SCR's.

Figure 3 uses no pulse transformer and can be extended to virtually any number of stages. When SCR1 is triggered, the cathode of SCR2 drops from +100 to essentially 0 Volts. Capacitor C1 discharges into the gate of SCR2

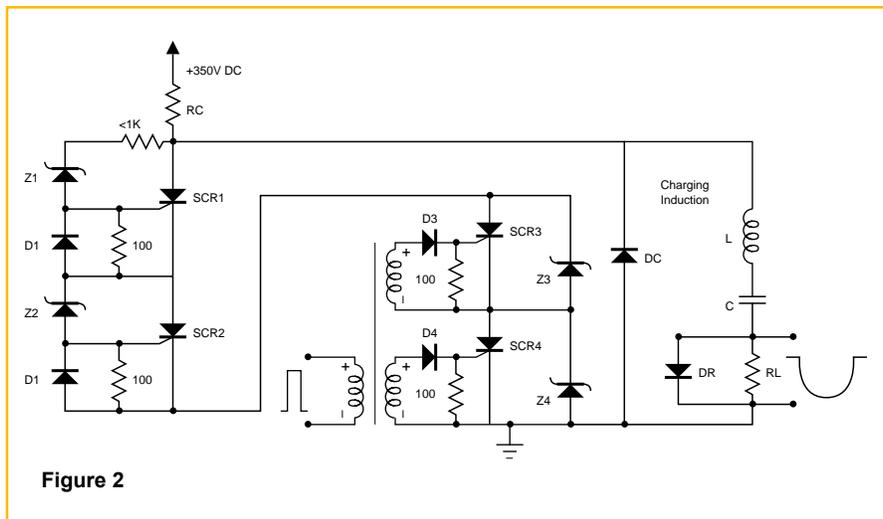


Figure 2

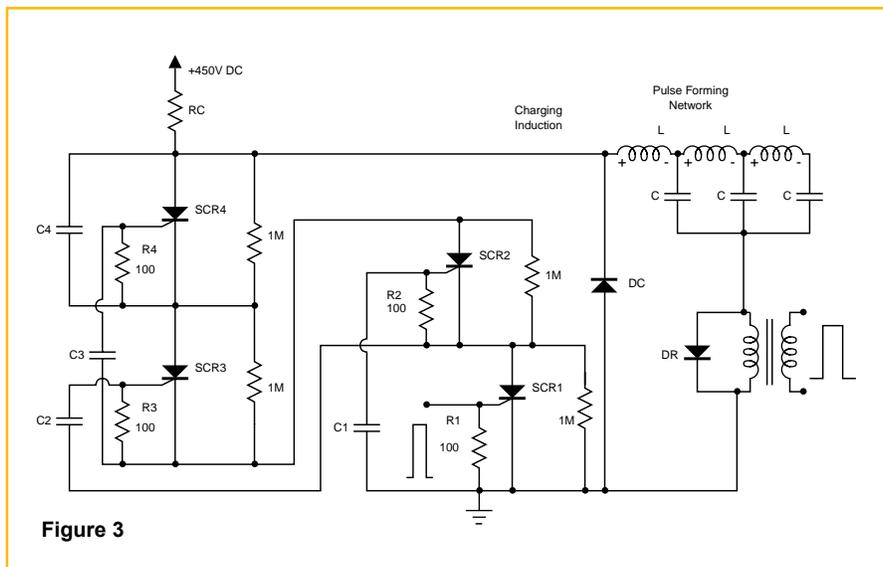


Figure 3

causing it to conduct, and this process is repeated for SCR3 and SCR4. This circuit has the added feature of providing a negative bias to the SCRs during recharge of the load, thus minimizing the effect of dv/dt. The product of fast rising voltage pulses (dv/dt) and the anode-to-gate capacitance of the SCR could result in a current in excess of the SCR's gate trigger current, Igt. As the voltage rises on the anode of SCR4, current flows through the path consisting of C4, R4, C3, R3, C2, R2, etc. This provides negative bias for the gate-to-cathode

junctions of each SCR in the string, making them less sensitive to dv/dt triggering. This allows the use of rapid re-charge circuits that permits operation at higher repetition rates. Either resonant recharge or active (SCR) rapid recharge techniques may be used with these circuits.

The total impedance in the SCR anode circuit must be set to a value sufficiently large to limit the DC current below the minimum holding current IH, of the SCR. This allows the SCR string to revert to the blocking state, ready for the next



trigger pulse. When the load contains an inductive component as is usually the case in modulator circuits, the network can be designed to “ring” in order to reverse-bias the SCR string momentarily, permitting the SCRs to regain forward blocking capability even if RC allows more than the minimum holding current to flow. Diode DR, may be used in all circuits so that the recharge current will not flow through the output element. In Figures 2 and 3, DR shunts the reverse “ringing” current around the output element. Diode DC, must be used in circuits that contain inductive elements to protect the string from being excessively back-biased due to circuit ringing. The design of the pulse-forming-network PFN, must meet the minimum requirements for efficiency. These include the need for a high-voltage square pulses with minimum droop between the leading and trailing edge. The selection of the inductance L, and capacitance C, components may be by selecting individual components or by cut-in coaxial line elements. In both cases the PFN represents an artificial transmission line which is charged

from a D-C power supply through an appropriate load. In the case of the coaxial line type PFN the surge impedance of the cable is

$$Z_o = \sqrt{L_o / C_o}$$

L_o is the inductance of the cable and C_o is the capacitance of the cable. If the cable is charged to a voltage (V) and is discharged through a resistance (RL), a current proportional to the voltage and inversely proportional to the sum of the load resistor RL and cable impedance Z_o flows through RL. The pulse current is sustained by a voltage wave ($V - R_L \times I$) which travels into the cable with a velocity proportional to the coaxial line length and inversely proportional to the square root of the product of $L_o \times C_o$. The wave will reflect at the far end of the cable, then return after time (T). The return time is double the inverse of the square root of the product $L_o \times C_o$. The current in the load is reduced slightly, (this is the droop between the leading edge and trailing edge of the wave form).

When the load resistance is matched to the cable ($R_L = Z_o$), the reflected wave terminates the pulse current and for this matched condition the pulse voltage is equal to $V/2$.

A charging reactor, or the first inductor in the PFN (see figure 2 and 3), normally isolates the high discharge currents from the power supply. This initial charging reactor is also important in preventing current flow immediately following the pulse interval.

Because of their low profile, economic utility, and high reliability, the Powermite[®] UPGA301A is uniquely suited to range finder circuitry and flash tube quench control applications in digital cameras. The basic circuit shown in figure 4 is a typical illustration of the UPGA301A applied to flash tube quench control circuitry.

