Solid State Relay and Application Circuits

SOLID STATE RELAY USING PHOTOCOUPLER

Figure 1 shows a solid state relay circuit using a photocoupler. Figure 1includes an input circuit, photocoupler, thyristor for triggering, rectifying diode bridge, snubber circuit, and high power triac. In operation, the photocoupler turns on the thyristor for triggering and its ON-current activates the high power triac to drive the load. Because of a low collector withstand voltage and the low output current of the photocoupler, a thyristor for triggering is needed to interface it with power control devices such as a power triac or power thyristor.

By appropriately choosing the R_1 and R_2 values, a high sensitive solid state relay having a wide range of input signal of the photocoupler type is realized. The zero-cross voltage is determined from the voltage division ratio by R_4 and R_5.

SOLID STATE RELAY USING PHOTOTHYRISTOR COUPLER

Figure 2 shows the drive circuit of thyristor using a half-wave control type photothyristor coupler.

Figure 3 shows the drive circuit of triac using a half-wave control type photothyristor coupler. In this circuit, D1 - D4 rectifying bridges are required for AC control using a half-wave control type photothyristor coupler.

Figure 4 shows the drive circuit of triac using a full-wave control type photothyristor coupler.

In each figure, R_1 is a resistor used to prevent mis-triggering of a large power thyristor and triac by leak current (I_{DRM}) when the photothyristor coupler is OFF. Therefore, the setting is required by checking the photothyristor coupler (I_{DRM}) and gate trigger current (I_{GT}) of a large power thyristor and triac. R_{S1}, R_{S2} and C_S form a snubber circuit.

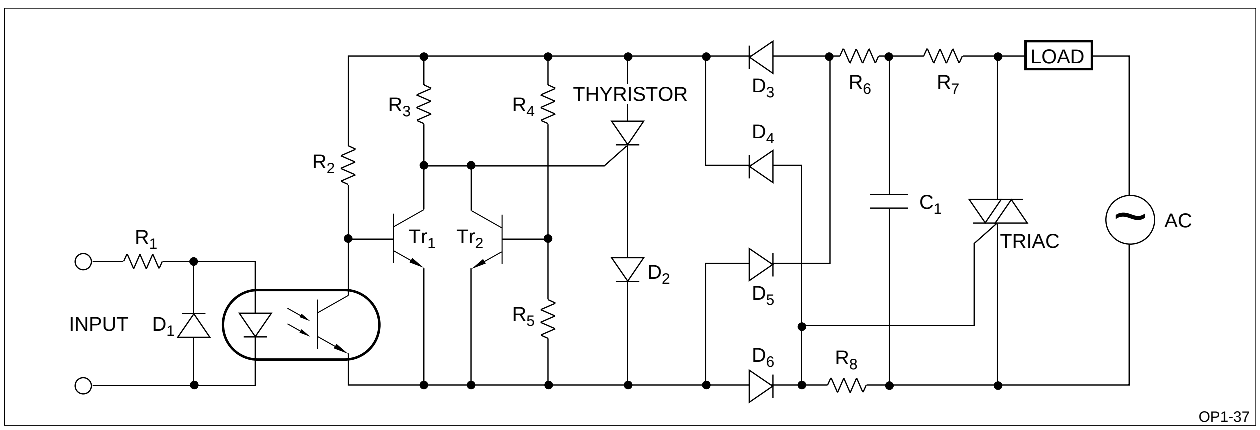


Figure 1. Solid State Relay with Built-in Zero-Cross Circuit

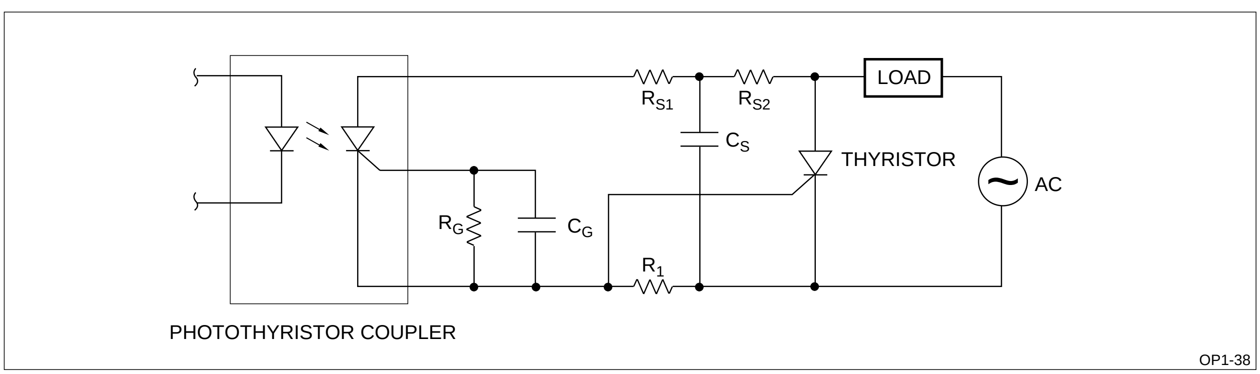


Figure 2. Large Power Thyristor Drive Circuit

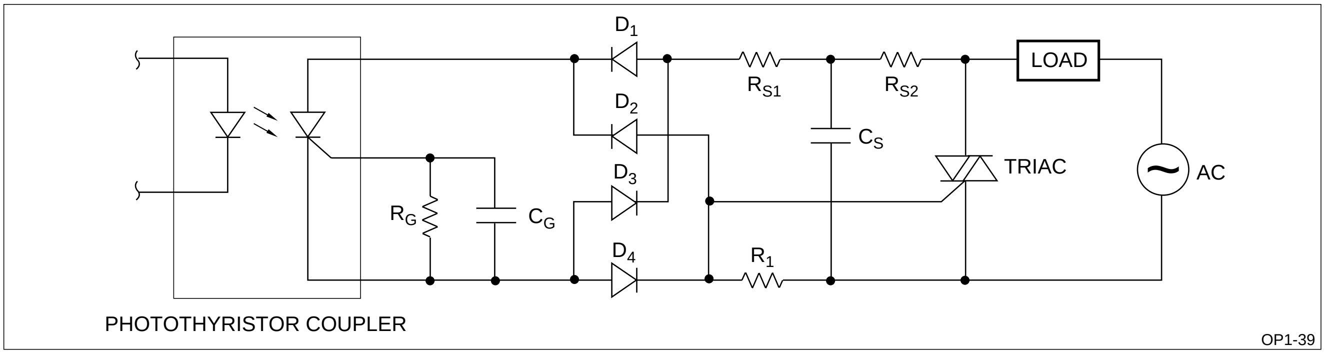


Figure 3. Triac Drive Circuit (I)

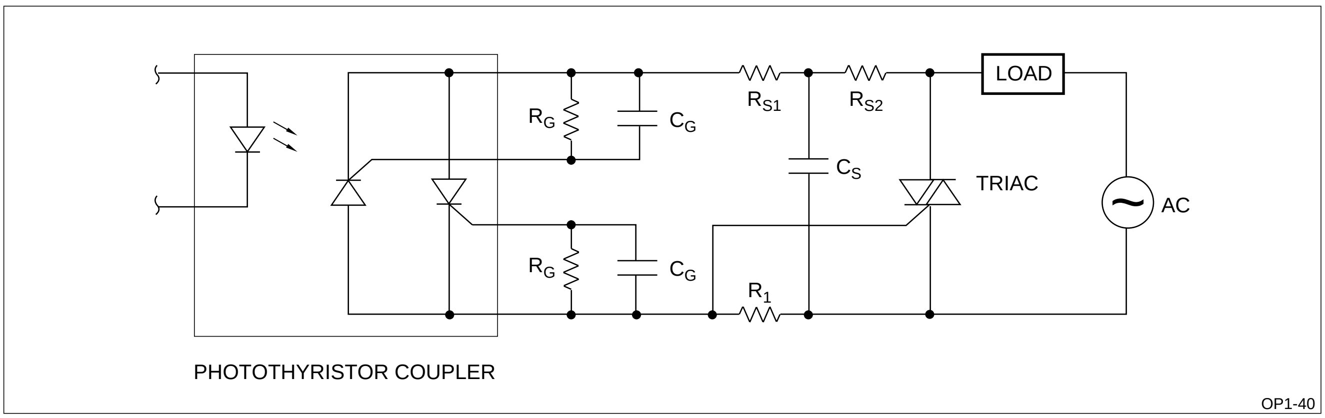


Figure 4. Triac Drive Circuit (II)

SOLID STATE RELAY USING PHOTOTRIAC COUPLER

Figure 5 shows the basic operating circuit of a triac using a phototriac coupler.

Figure 6 shows a circuit example of controlling forward and reverse rotation of the motor, using a control signal as one example of phototriac coupler application circuit.

INPUT DRIVE CIRCUIT

Figure 7 shows the input drive circuit of a solid state relay (SSR). (A) and (B) operate with a positive signal, and (C) and (D) operate with a negative signal. (B) and (C) are effective when the output current of control circuit is small.

(E) is a drive circuit using IC (TTL/DTL), which operates when IC is in the 'L' state.

(F) and (G) are drive circuits using CMOS IC, each of which cannot drive the primary side of SSR with CMOS IC only; it therefore drives via a transistor.

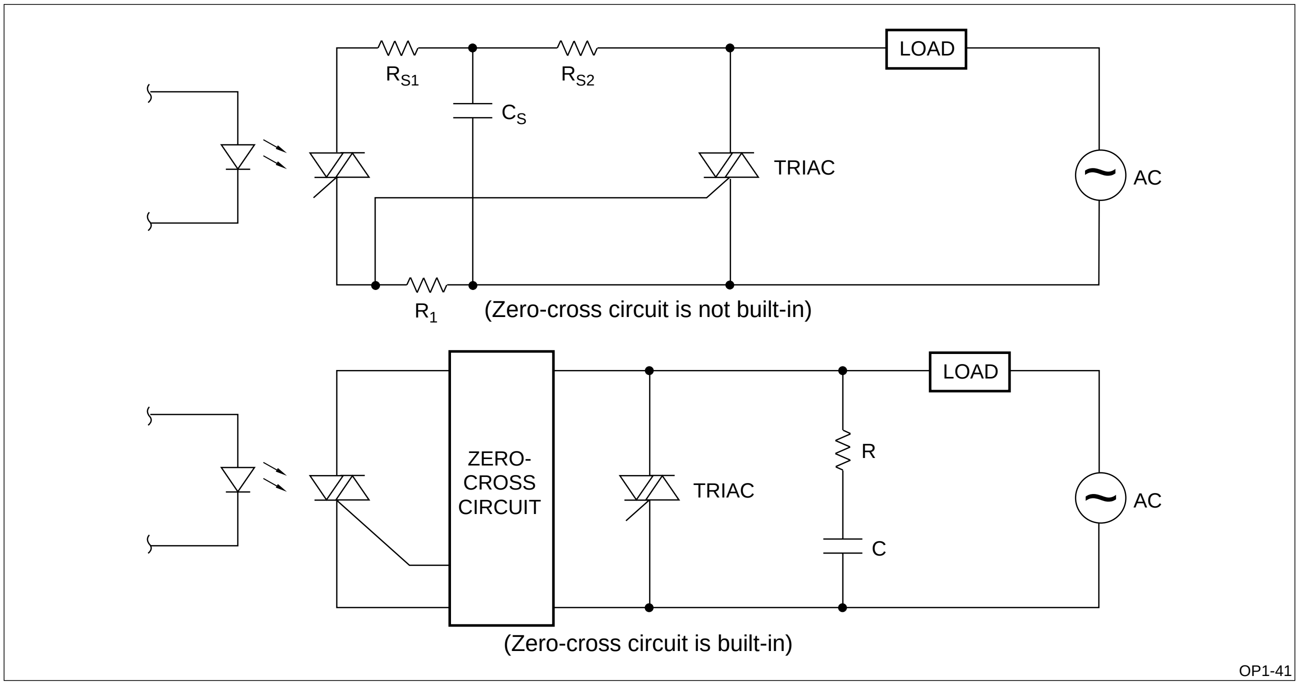


Figure 5. Triac Drive Circuit (III)

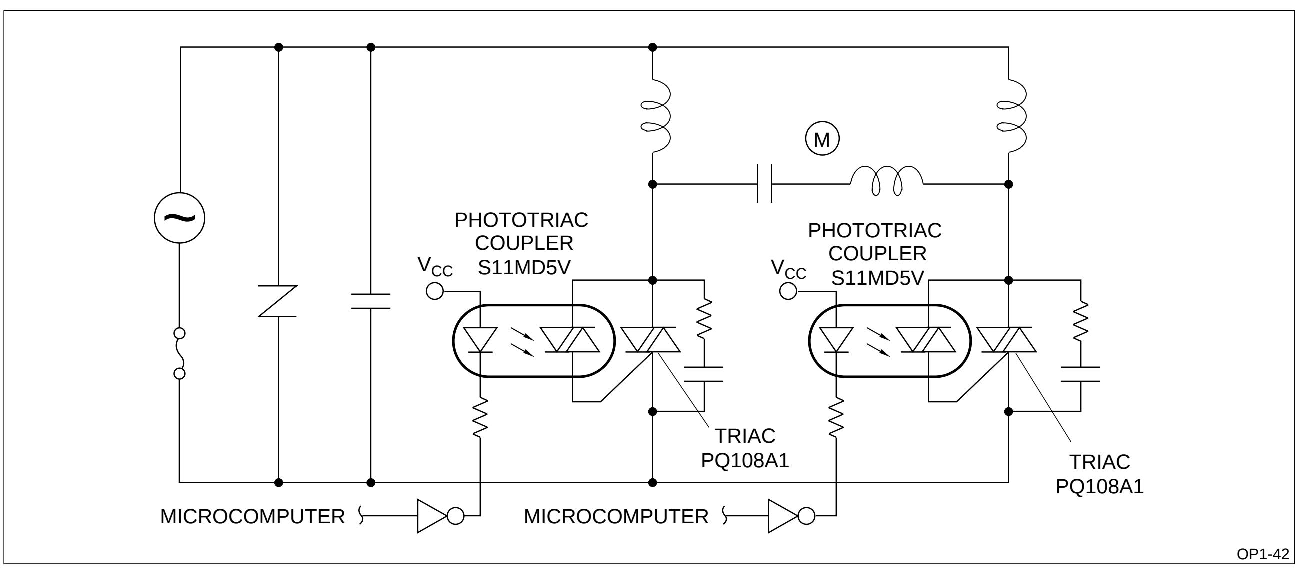
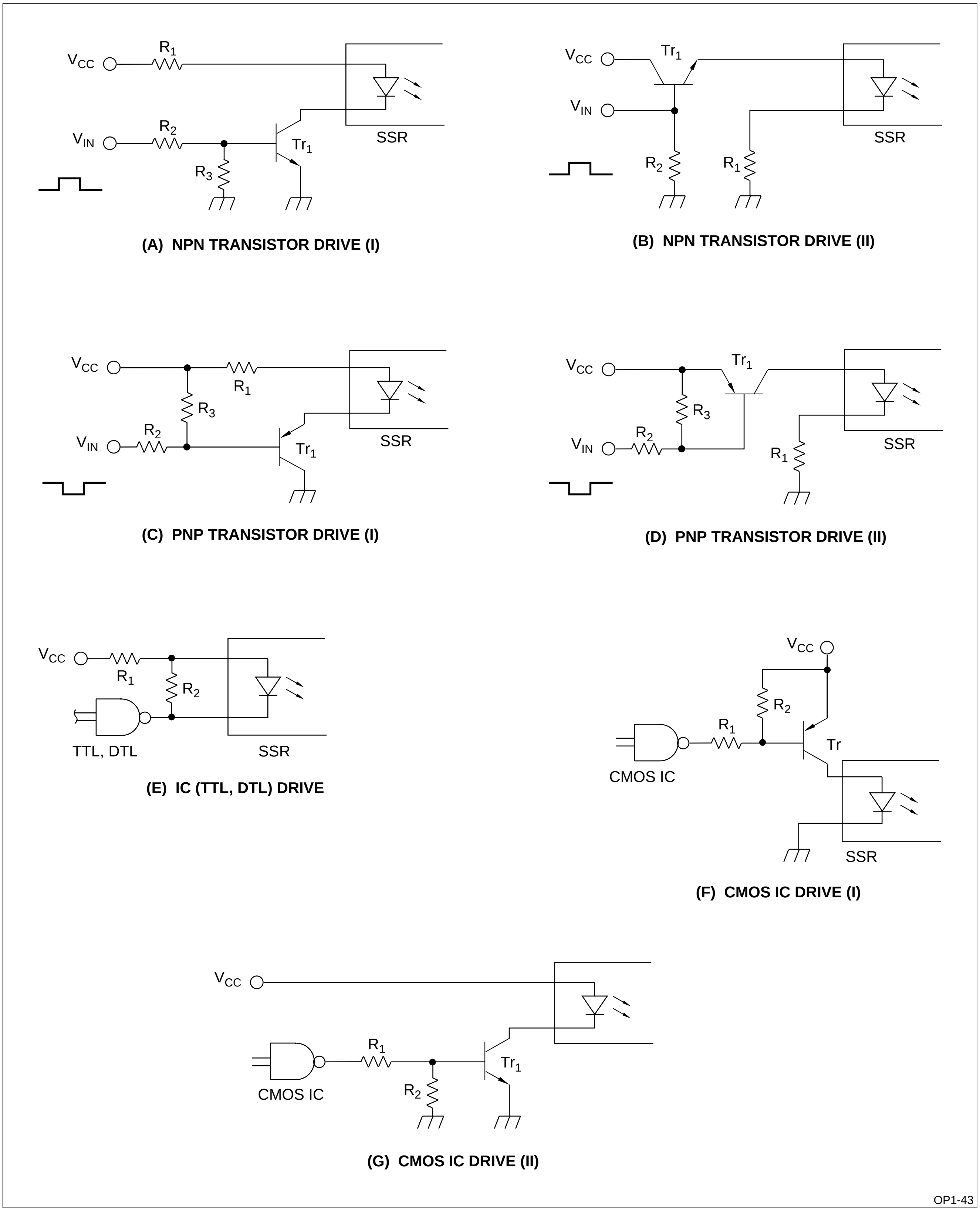


Figure 6. Motor Drive Circuit



(A) NPN TRANSISTOR DRIVE (I)

(B) NPN TRANSISTOR DRIVE (II)

(C) PNP TRANSISTOR DRIVE (I)

(D) PNP TRANSISTOR DRIVE (II)

(E) IC (TTL, DTL) DRIVE

(F) CMOS IC DRIVE (I)

(G) CMOS IC DRIVE (II)

Figure 7. Input Drive Circuit

ARRIVAL BELL SIGNAL DETECTION OF TELEPHONE

Figure 8 shows a circuit for transmitting an arrival bell signal to a telephone related device while maintaining the electrical isolation between the device and the telephone subscriber line. The ring signal is an AC signal (75 Vrms, 16 Hz) superimposed on the 48 V line.

A non-polarized photocoupler (designed for AC input response) is suited for this purpose.

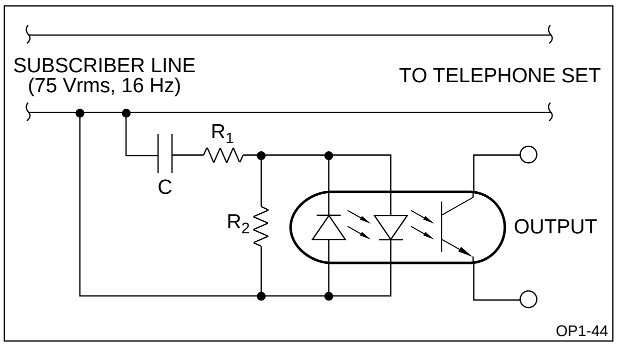


Figure 8. Telephone Arrival Bell Signal Detection

SOLID STATE APPLICATION CIRCUITS

Solid sate relays (SSR) have extensive applications, from industrial equipment to home appliances, including triggering SSRs for activating high power thyristors and triacs and power control SSRs for directly switching AC loads

SNUBBER CIRCUIT

Application of a voltage above the rating at the output side of SSR would result in a malfunction or even destruction of the device due to overcurrent. The snubber circuit is designed to absorb and suppress impulse noise.

Figure 9 shows some examples of a snubber circuit. Circuit (A) is most commonly used for CR absorbers. Circuit (B) is more effective for noise absorption since it can have a smaller Rg value. Circuit (C) uses a varistor which can absorb high energy noise such as that caused by lightning.

The values of the resistors and capacitors in the snubber circuit depend on the kind of load and power capacity.

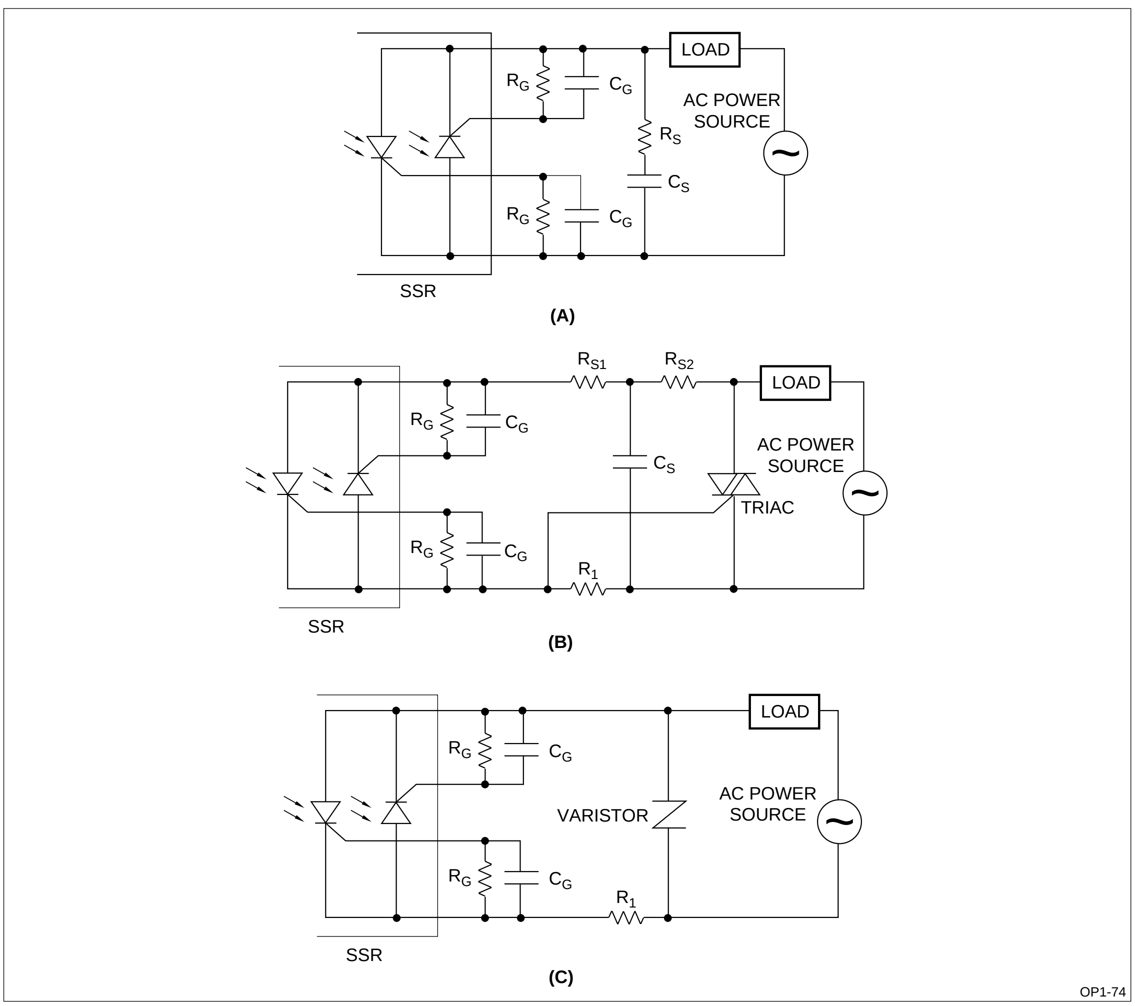


Figure 9. Snubber Circuits

SERIAL/PARALLEL CONNECTIONS

Figure 10 and 11 show the circuit of two SSRs connected in series and parallel, respectively. The following precautions should be considered when operating two photothyristor type SSRs connected in series or parallel.

For Serial Connections:

Due to dispersion of leak current in forward and reverse of photothyristors, there can be a difference in the voltage across each device. For this reason, a resistor (R_1, R_2) is connected in parallel with each device so as to minimize the voltage difference.

There is dispersion in the critical rate of rise of off-state voltage (dV/dt) among photothyristors depending on the junction capacity and sensitivity of devices. For this reason, the serial connection of resistor and capacitor (R_S, C_S) is connected in parallel to each device so that both SSRs are balanced.

For Parallel Connections:

Two SSRs connected in parallel must be turned on simultaneously. If one SSR turns on first, the other SSR has both its terminals short-circuited through the first one and possibly cannot turn on even if the device has low on-voltage characteristics. For this reason, adjustments must be done through the gate resistor or gate capacitor so that both SSRs have an equal turn-on time.

There are slight differences in the turn-on voltage according to devices. This causes an unbalanced current distribution among the photothyristors, resulting in the possibility of an overcurrent. On this account, a resistor of low resistance is connected serially to the photothyristor so as to adjust the on-voltage. This equalizes the current distribution in both devices.

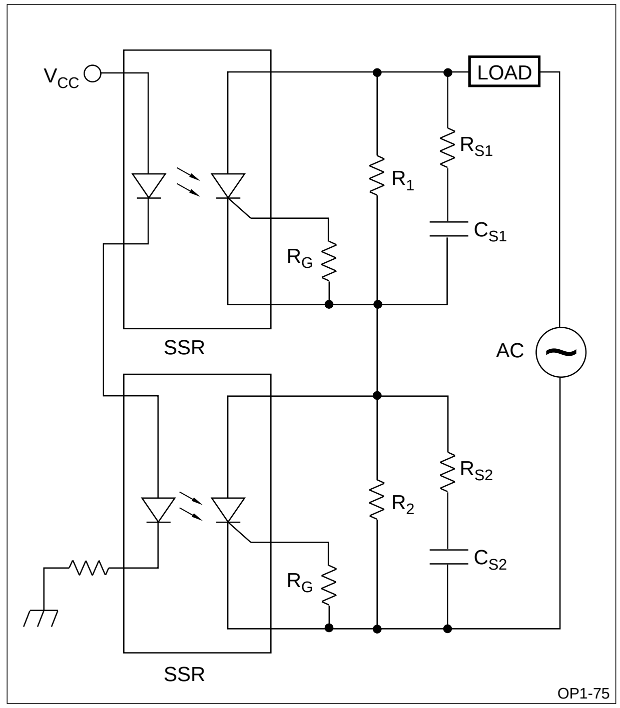


Figure 10. Serial Connection Example

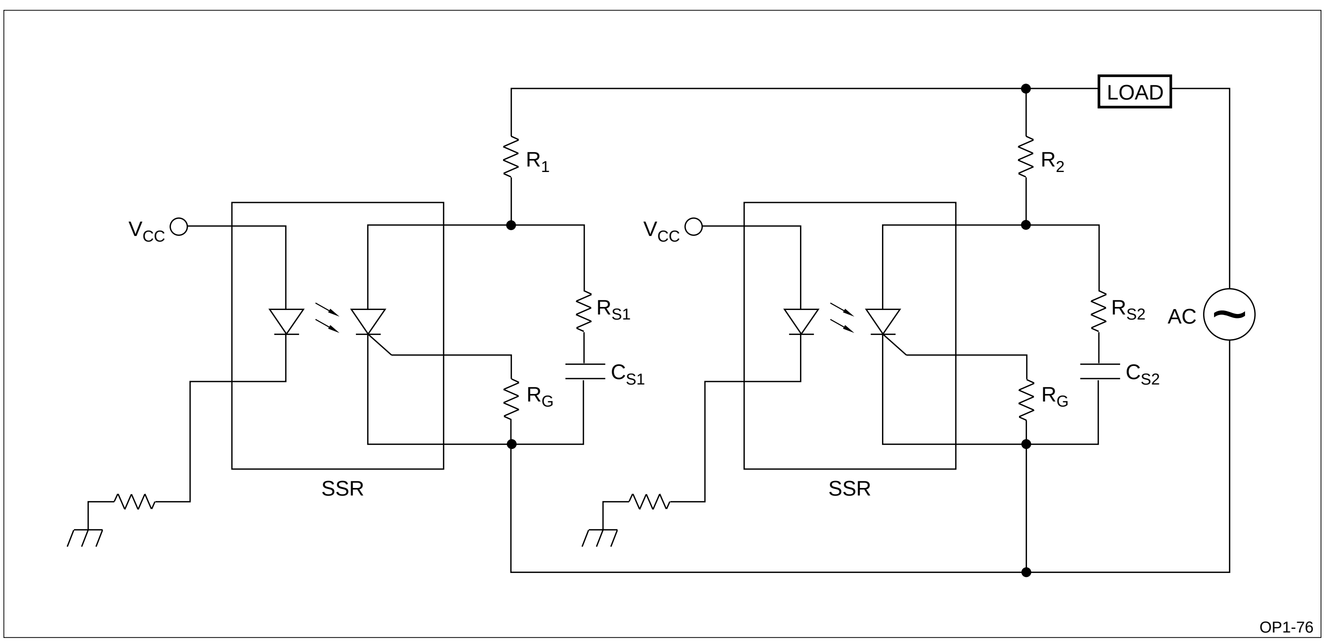


Figure 11. Parallel Connection Example

Zero-cross circuit

Figure 12 shows a zero-cross circuit using photocouplers. As shown in waveforms A and B, both photocouplers are off around the zero voltage level of the AC power voltage. One of the photocouplers is on in the remaining time. Accordingly, a zero-detect signal can be produced by taking the logical product of signals A and B. A zero-cross made SSR is thus arranged through activation of the SSR by the zero-detect signal Q.

This system is particularly useful in operating multi-channel SSRs in a zero-cross mode in a programmable controller, etc.

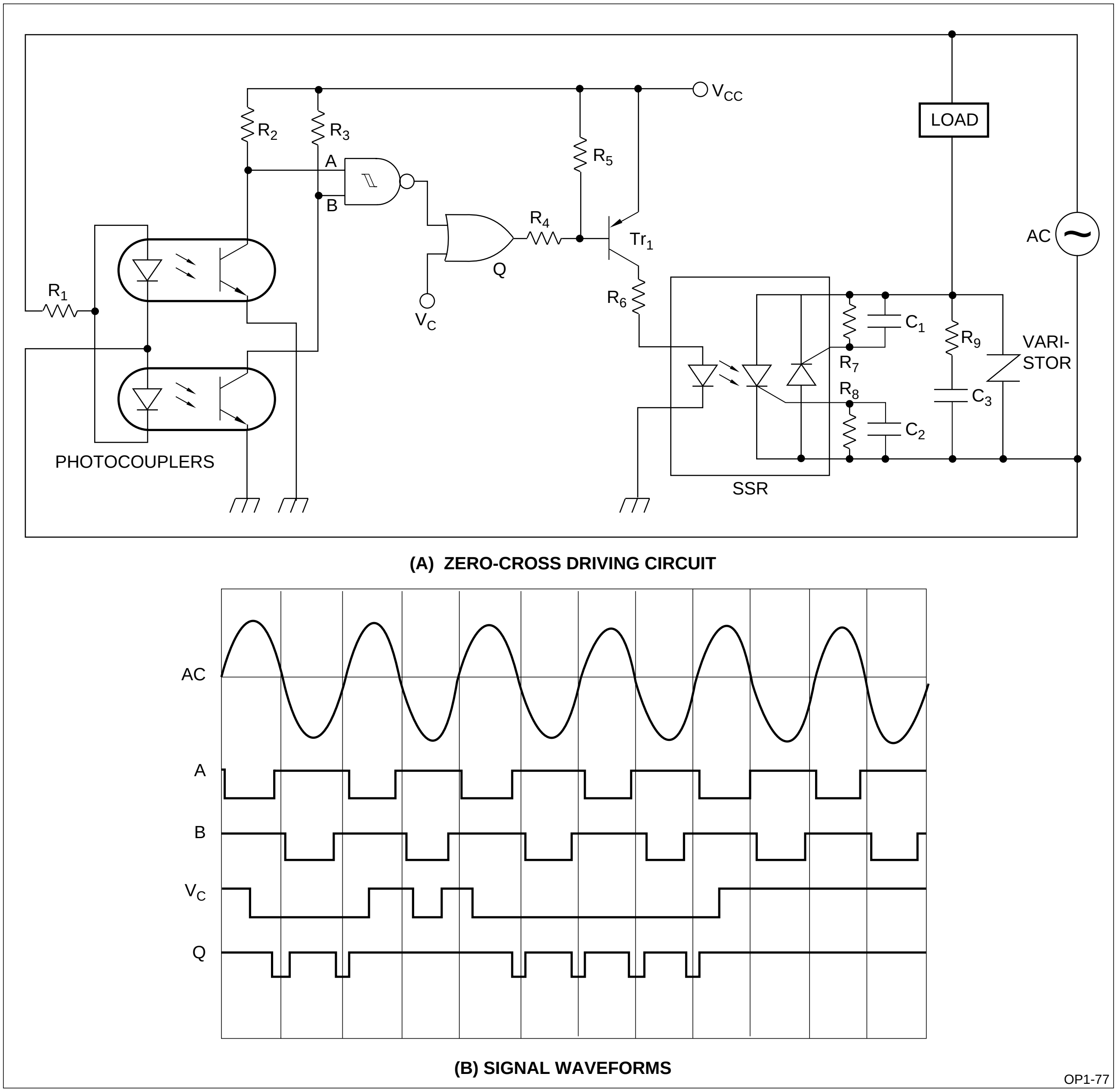


Figure 12. Zero-Cross Circuit

APPLICATION CIRCUITS OF SSR

Programmable Controller

A programmable controller is a sequence controller which takes the place of conventional relay sequence controllers. It consists of a CPU, memory, I/O interface and peripheral devices for programming. The input/output unit of the programmable controller employs photocouplers for the input post and photocouplers or SSRs for the output in place of conventional relay contacts.

Figure 13 shows the circuit of an output unit including 8 or 16 SSRs. The SIP-type SSR features a compact, built-in snubber circuit and input current limiting resistors and is frequently used in modern programmable controllers.

Figure 14 is a block diagram of a typical programmable controller.

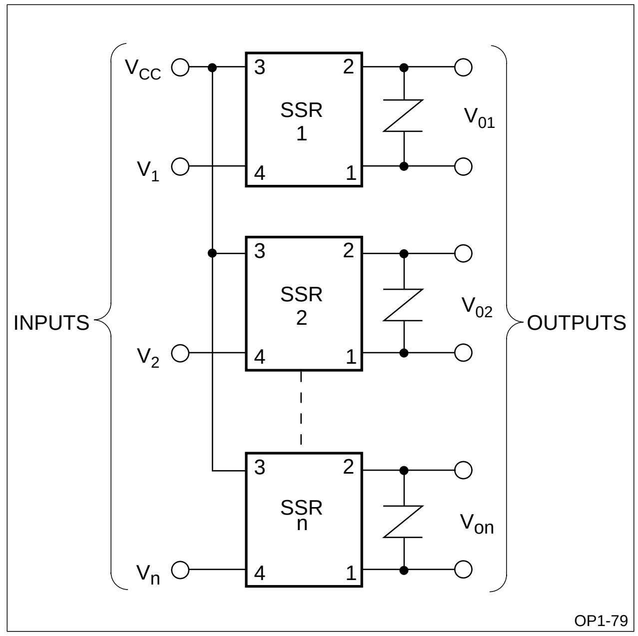


Figure 13. Programmable Controller Output Unit

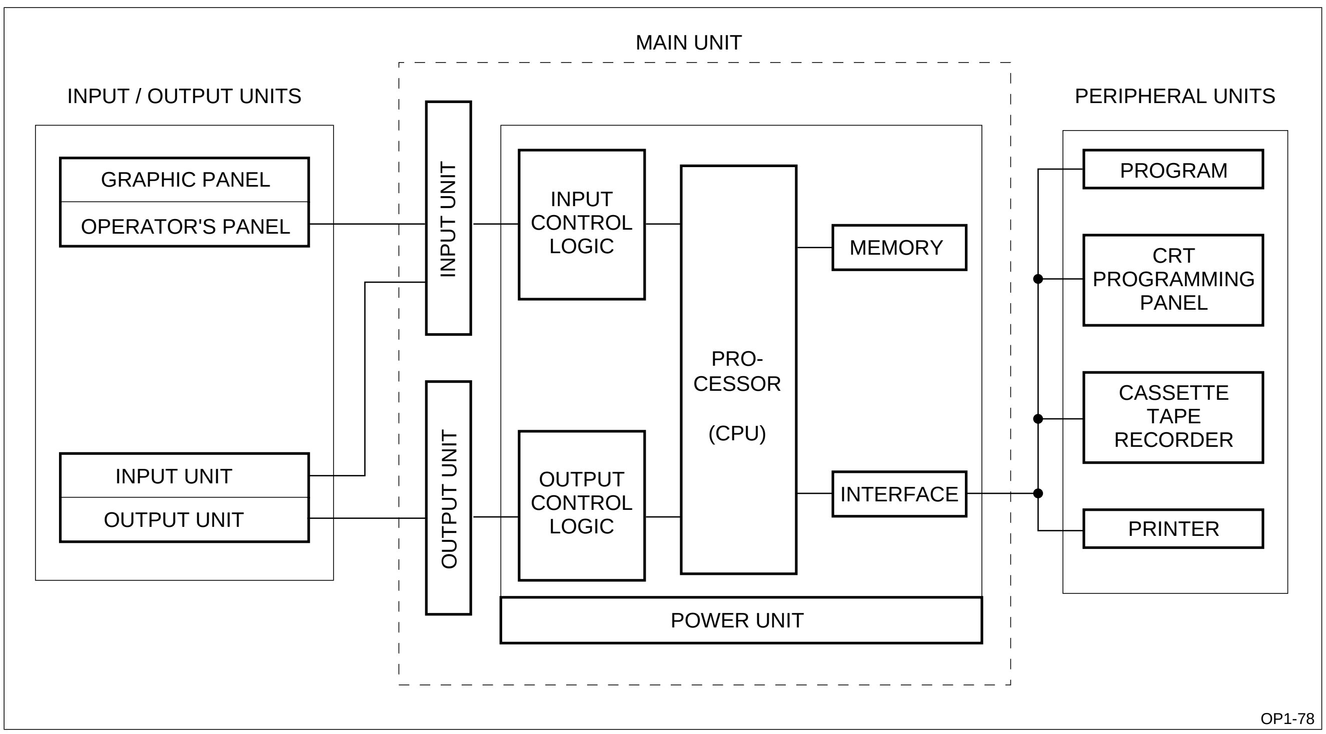


Figure 14. Block Diagram of Programmable Controller

Copier

Figure 15 (A) shows an internal view of a copy machine in which SSRs are used. Figure 15 (B) shows a circuit example of the copy lamp control circuit using SSRs.

The copy lamp has a start-up period of several power cycles in which a rush current 10 times or more than the steady-state current flows as shown in Figure 15 (C), activating the control circuits of Figure 15 (B). Here, the SSR is shunted by resistor R_1 so as to supply a small current to the lamp for preheating, which reduces the rush current when starting.

Reversible Motor Driver

Figure 16 (A) shows the circuit of a reversible motor driver using an SSR. The circuit operates in response to the input signal shown in Figure 16 (B) to produce the motor current and voltage shown in Figure 16 (C).

The reversible motor is driven in the forward or reverse direction by one of two SSRs. If both SSRs are made conductive simultaneously, the motor will overheat. To prevent this, a time length of 1/2 cycle or more is used in switching the rotational direction as shown in Figure 16 (B). Each SSR is applied across its output terminals with a voltage twice the peak-to-peak voltage of the power line. Therefore, for a 100 VAC power source, SSRs with a withstand voltage of 300 V or more must be used.

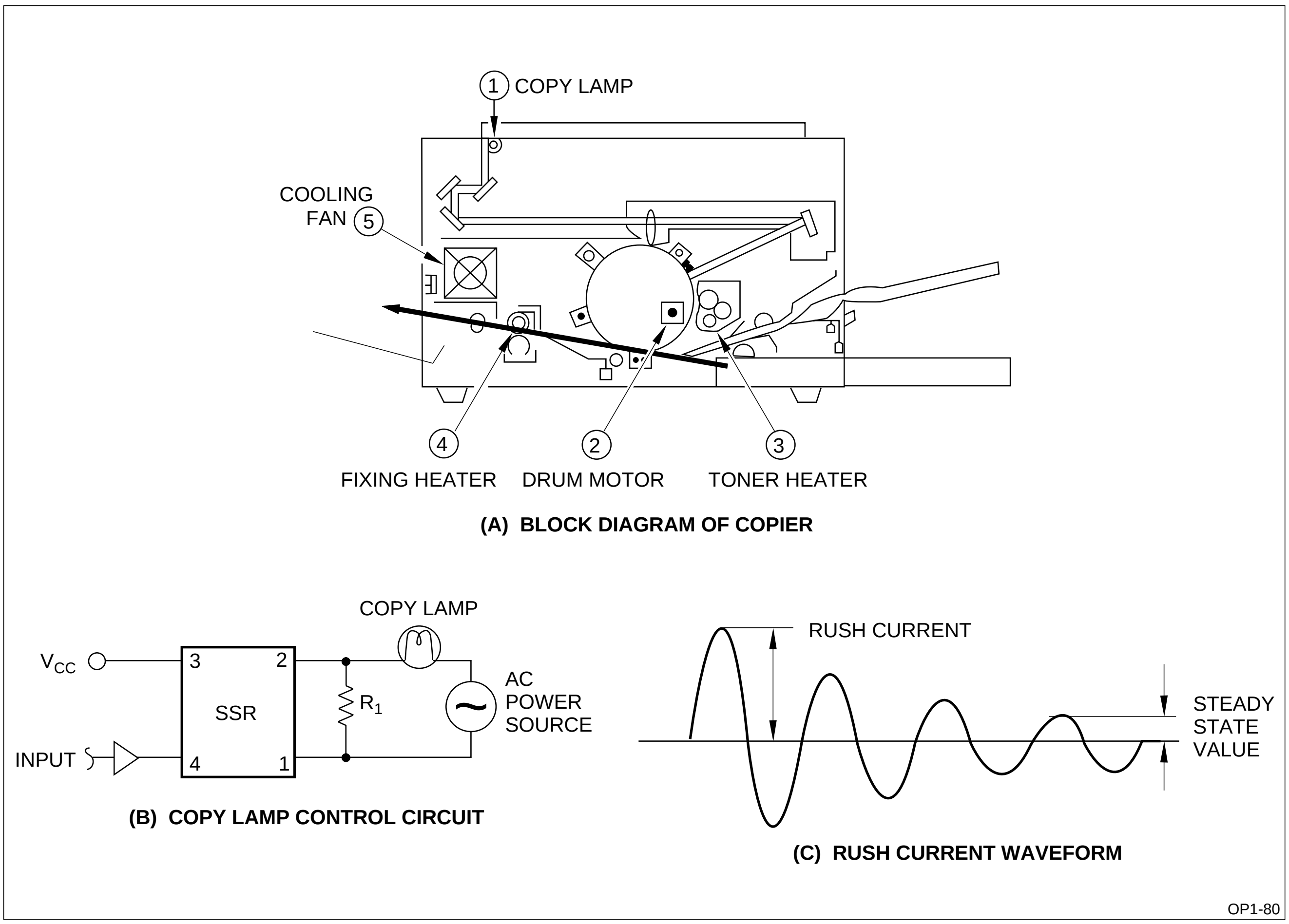


Figure 15. Copier

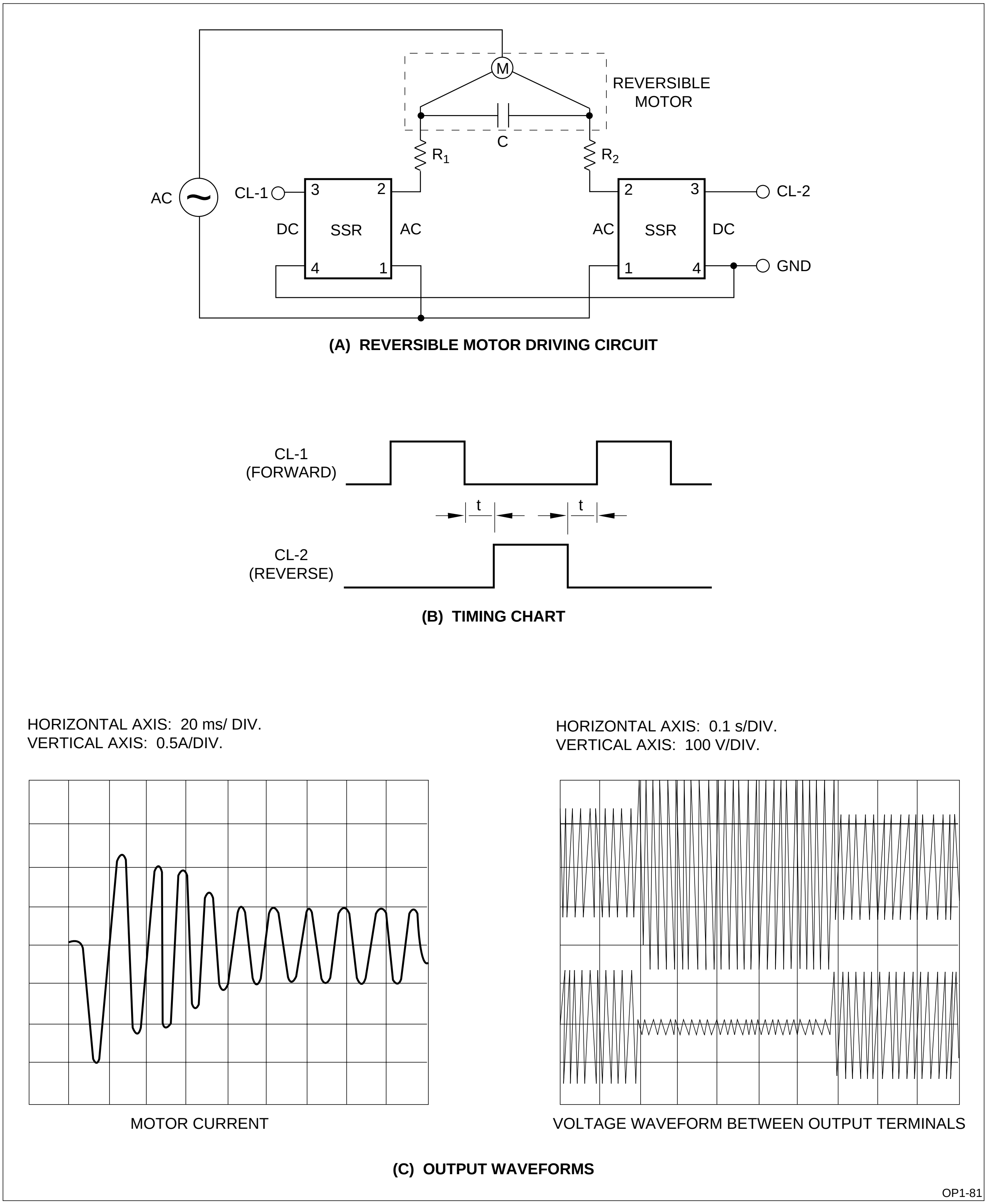


Figure 16. Reversible Motor Drive

Heater Control Circuit

Figure 17 shows a heater control circuit designed to maintain a constant temperature. A copper-constant thermocoupler is used as a temperature sensor. An SSR is used to switch the power to the heater. The circuit shown features a wide temperature setting range and high control accuracy. Setup is made by a variable resistor (VR).

Microcomputerized Rice Cooker

In the circuit arrangement of Figure 18, three heaters (a main heater, side heater and lid heater) installed in a rice cooker are controlled by two SSRs. The three heaters are connected in series. The side and lid heaters are short-circuited by the cooking SSR during the cooking, while the warming SSR is turned on and off cyclically on completion of cooking so as to maintain a constant temperature inside the rice cooker.

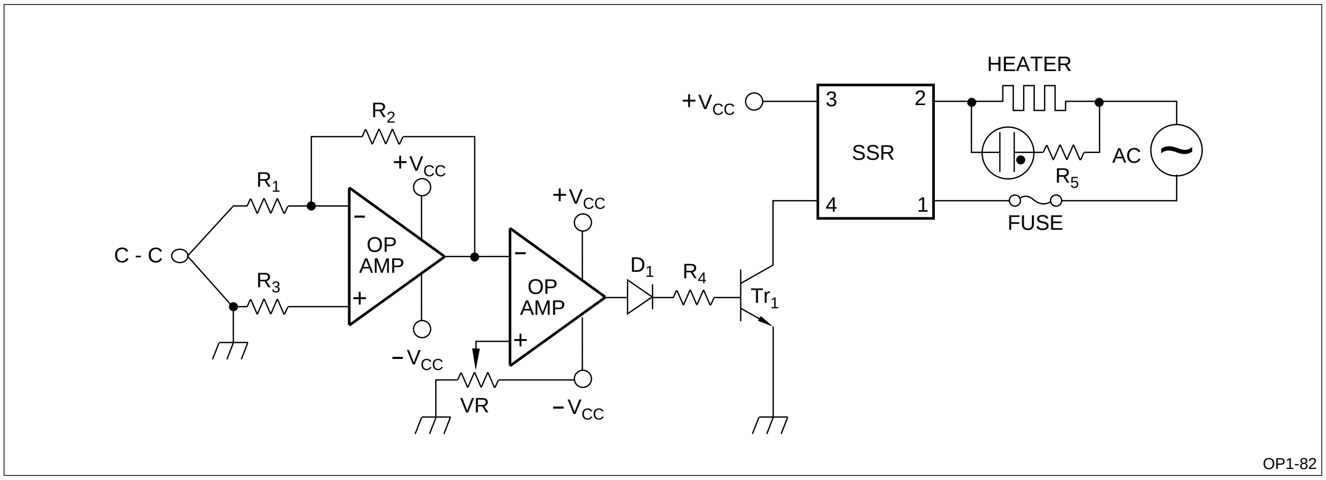


Figure 17. Heater Control Circuit

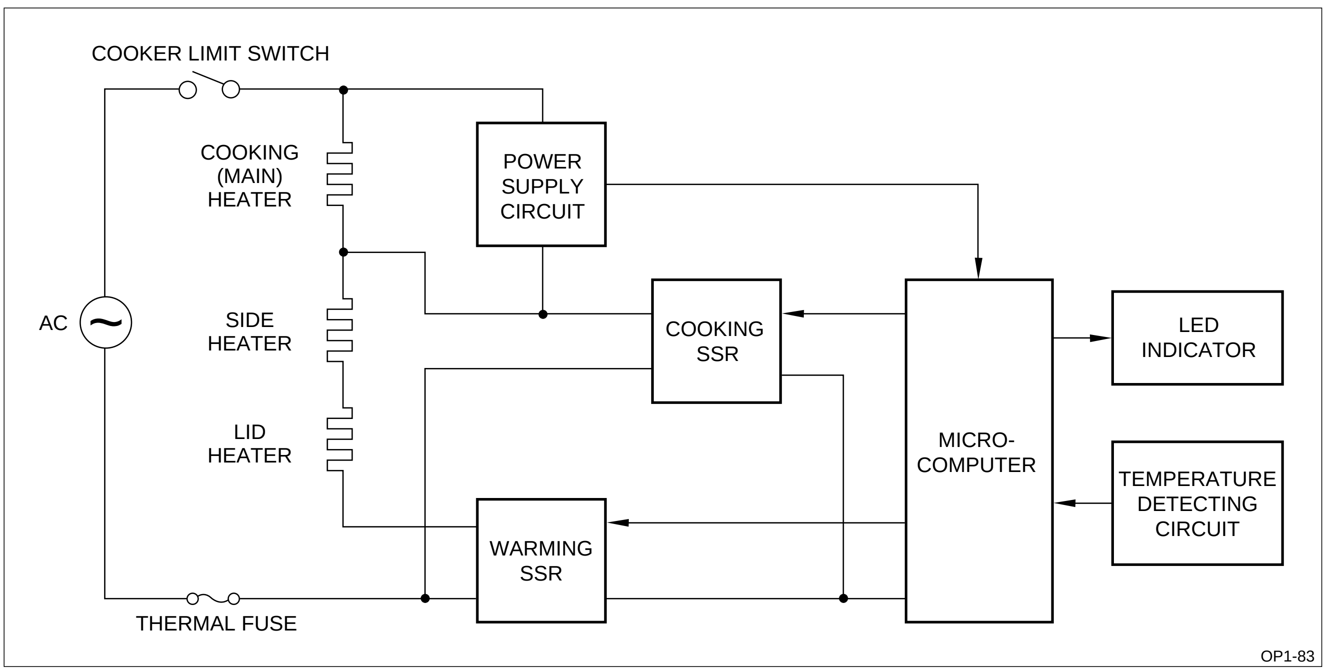


Figure 18. Microcomputerized Cooker

Table 1. SSR Application Fields

FIELD	EQUIPMENT	APPLICATIONS
Home appliances	Air conditioners	On/off control of compressor, speed control of blower motor
	Washing machine	Speed control pulsator
	Refrigerators	On/off control of compressor, defrosting circuit
	Electric blankets	Automatic temperature control
	Electric carpets	Automatic temperature control
	Electric jars	Automatic temperature control
	Electric powered tools	Motor speed control
	Electric sewing machines	Motor speed control
Office equipment	Copiers	On/off control of copy lamp, heater control
	Facsimiles	Speed control of motor (drum)
	Computer	Power switching of peripheral equipment
	Printers	On/off and speed control of motor
	Photograph processors	Exposure control
Automobiles	Ignition system	Switching of discharge circuit
	Generators	Output voltage control
	Others	On/off control of wiper motor and side mirror motor
Automatic vending machines	Coin sensors	Interface between coin sensor and indicator
	Vendors	On/off control of solenoid and indicator
Control equipment	Electric furnaces	On/off and temperature control of heater
	Process controllers	On/off and speed control of motor, on/off control of solenoid
	Programmable controllers	Output board (interface)
	Numerical control machines	On/off control of motor and solenoid
	Elevators	On/off control of indicator lamp, open/close control of door, on/off control of fan motor
Illuminators and others	Traffic signals	Flickering control of lamp
	Electric sign boards	On/off control of road information lamp
	Fluorescent lamps	Lighting circuit
	Illumination controllers	Phase control circuit

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