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Application Note

Phase-out/Discontinued

APPLICATION CIRCUITS USING POWER MOS FET

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Phase-out/Discontinued

The application circuits and their parameters are for reference only and are not intended for use in actual design-ins.

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In recent years, power MOS FET deserves attention as high speed switching power device, instead of conventional bipolar transistor.

The main reasons are the followings;

1) Power MOS FET, which is a voltage drive type, restrains drive loss.

2) Power MOS FET, which is a majority-carrier device, makes switching speed over 10 times faster than bipolar transistor.

3) Unlike bipolar transistor, power MOS FET suffers no secondary breakdown, and so voltage and current values remain well within the rated power, etc.

Then, power MOS FET is apparently superior to conventional bipolar transistor in many ways. So the application of power MOS FET is spreading rapidly throughout all fields, not only switching power supply but OA, Automotive and so on.

This data sheet describes the application circuits using power MOS FET and is confined to principal explanation. So it is necessary to make an examination in detail for circuit design.

1. Switching power supply I

Figure 1 shows a frequency 80 kHz, output 100 W line operated switching power supply using the 2SK854 power MOS FET.

Photograph 1 shows the waveform and Table 1 does the measure data, switching time and case temperature rise in case of comparing between 2SC2751 (400 V/10 A) and 2SK854 (450 V/5 A).

As Table 1 shows, the power dissipation of switching power supply using power MOS FET is lower than that using bipolar transistor because the switching time of power MOS FET is over 10 times faster than that of bipolar transistor.

As figure 1 shows, when bipolar transistor is used in parallel operation, bipolar transistor needs the small source resistance (R_1 and R_2).

On the other hand, power MOS FET doesn't need it in such a case, because drain to source on-state resistance of power MOS FET is positive temperature coefficient.

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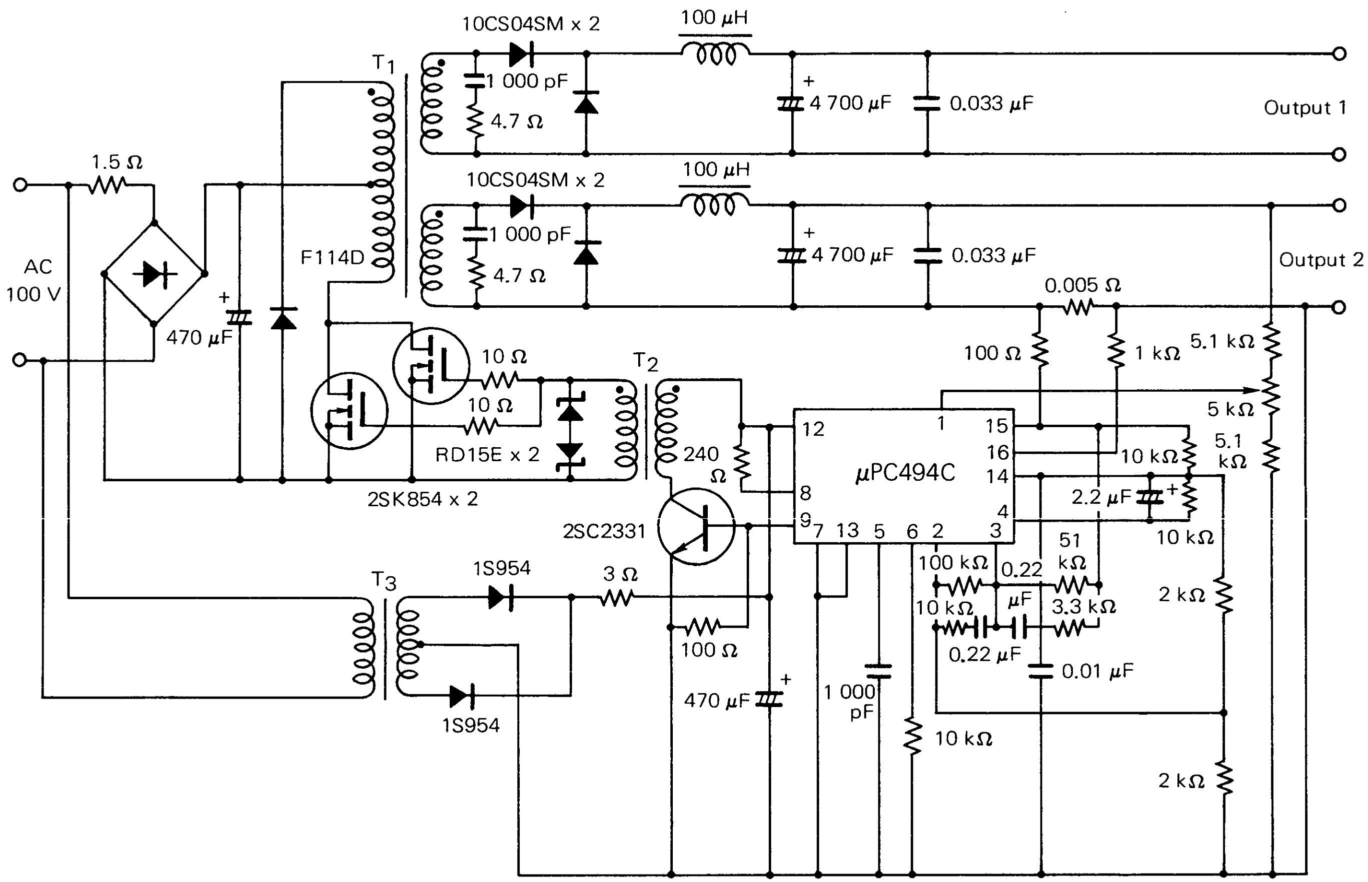
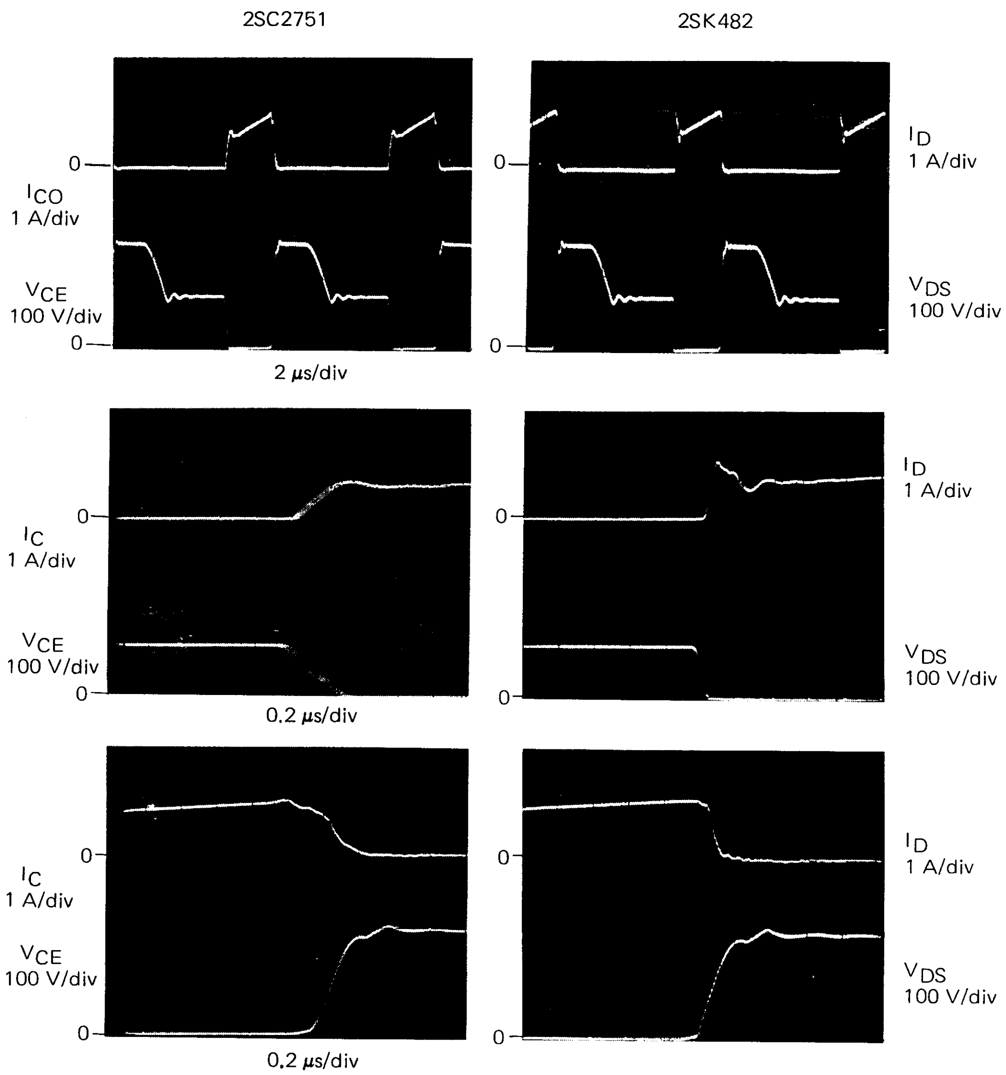


Fig. 1 Secondary control method switching power supply using 2SK854

Table 1: Comparison between 2SC2751 and 2SK854 at 80 kHz switching power supply

Item \ Type No.		2SC2751	2SK854
package		MP-80	TO-220
switching time	t_r	0.26 μs	0.05 μs
	t_r	0.30 μs	0.08 μs
case temperature rise		56 °C	21°C

Photograph 1



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2. Switching power supply II

Figure 2 shows high frequency 200 kHz, output 100 W switching power supply application circuits in primary control method using switching regulator control IC (μPC1094C) up to 500 kHz switching frequency.

Improvement of switching frequency in switching power supply is indispensable for evolution which makes switching regulator smaller, and cheaper.

Then a primary control method, shown in Figure 2, will become the main current hereafter. And power MOS FET capable of high switching operation will give full play to its merits and be used well.

Especially, in case that switching frequency is over 100 kHz like the high frequency switching regulator (the switching frequency is 100 to 300 kHz) shown in Figure 2, power MOS FET is superior to bipolar transistor by reason of the followings;

1) Power MOS FET is a voltage drive type and is capable of being directly driven by control IC as Figure 2 shows, and so it simplifies a drive circuit and reduces drive power.
2) Power MOS FET is a majority-carrier device and no effect of storage, and so it is capable of high speed switching.
3) Power MOS FET suffers no secondary breakdown and can make parallel operation easy because $R_{DS(on)}$ – drain to source on-state resistance, has a positive temperature coefficient.

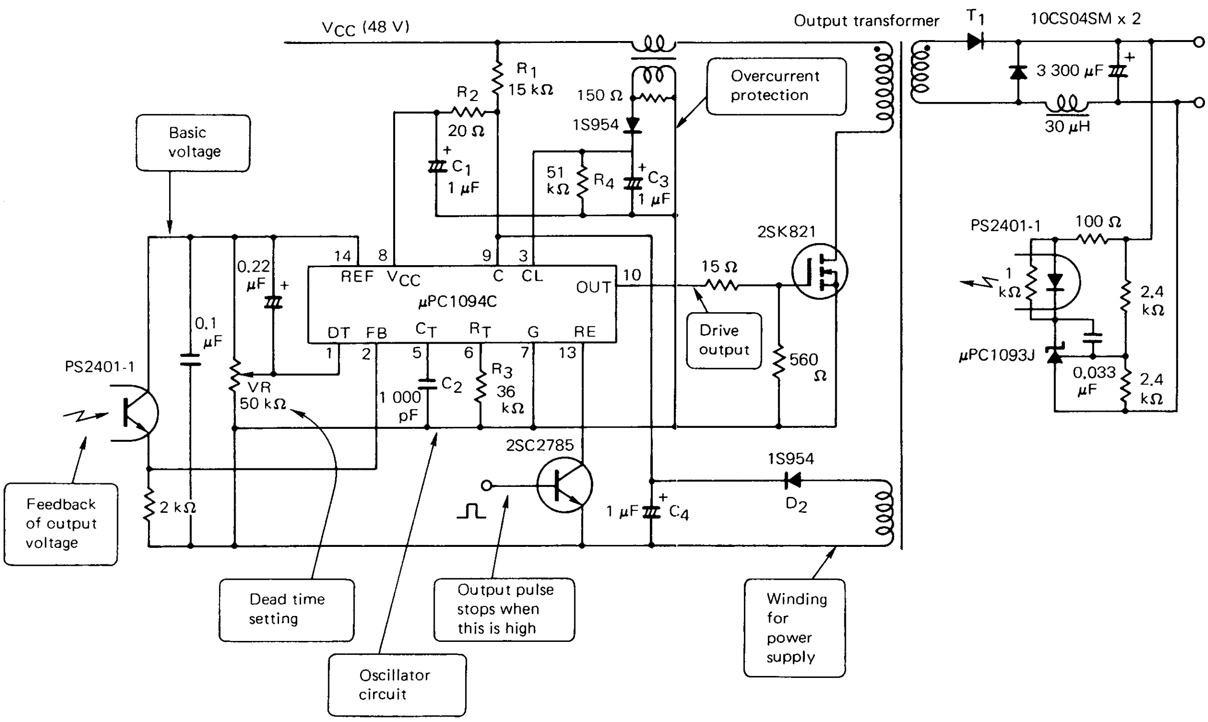

Fig. 2 Primary control method switching power supply using 2SK821

3. Rectifier Circuit

As the efficiency of the switching power source improves because of the use of power MOS FET devices, the resulting power dissipation of the secondary rectifier circuit becomes significant. The reduction of the power dissipation is now required. Figure 3 shows a typical high-efficiency rectifier circuit using two MOS FET devices.

Before discussing the operation of the rectifier circuit, we must explain the inversion characteristics between the drain and source caused by gate-biasing of the power MOS FET.

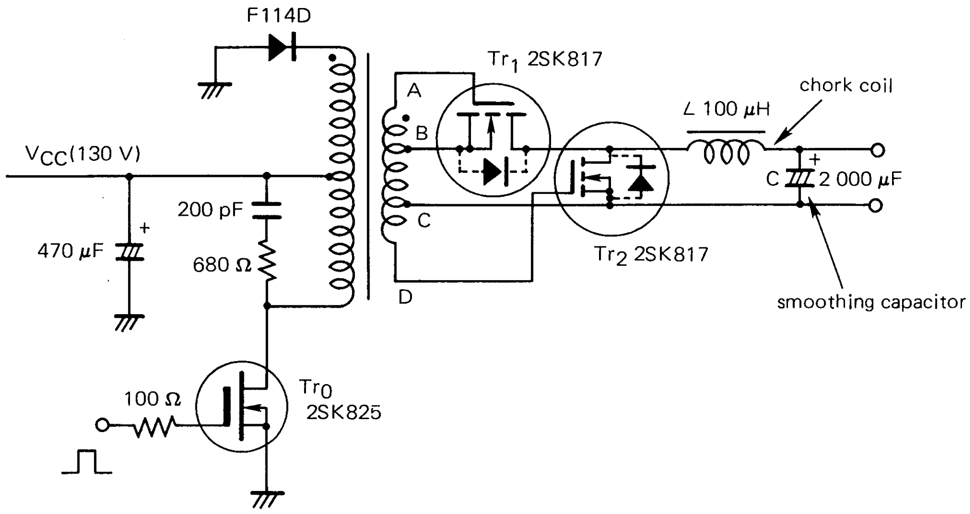

Fig. 3 (a) Low loss rectifier circuit using power MOS FET

Figure 3(b) shows the inversion characteristics of the power MOS FET. If the gate is reverse-biased or is not biased, the inversion characteristic of the power MOS FET is the forward-voltage versus current characteristic of the body diode. If the gate is forward-biased, the MOS FET in parallel with the body diode conducts and the resistance characteristic of the power MOS FET is the same as the forward on-state resistance characteristic. The rectifier circuit shown in figure 10 uses the above characteristics properly.

While the points indicated by dots on the transformer windings in figure 10 are positive, the gate of power MOS FET Q_1 is forward-biased. The resistance between the Q_1 source and drain is the low (low on-resistance) and the body diode conducts. The gate of another power MOS FET, Q_2, being reverse-biased, is cut off. Current therefore flows in the sequence of points on the secondary winding of the transformer, power MOS FET Q_1, smoothing coil, and the smoothing capacitor. While the transformer points indicated by dots are negative, the gate of power MOS FET Q_1 is reverse-biased and cut off.

A flywheel current intended to flow through the smoothing coil, and the smoothing capacitor, and body diode of power MOS FET Q_2 is forward-biased and the source-drain resistance is low.

The power MOS FET devices perform rectification in this manner. The body diode is inactive and the resulting inversion recovery time of the body diode is not generated because the voltage drop created by the drain-to-source resistance is much smaller than that of the body diode (when the gate is forward-biased). The 2SK817 4 V Gate-Driven Low On-State Resistance Power MOS FET ($R_{DS(on)}$ of 35 mΩ/45 mΩ, at V_{GS} OF 10 V/4 V), with a voltage drop of about 0.2 V at a current 5 A, is more efficient. than any other Schottky-barrier diode (voltage drop of 0.5 V).

Figure 12 shows a typical high-efficiency rectifier circuit using two MOS FET devices of a negative power source. The rectifier requires no auxiliary secondary winding of the transformer.

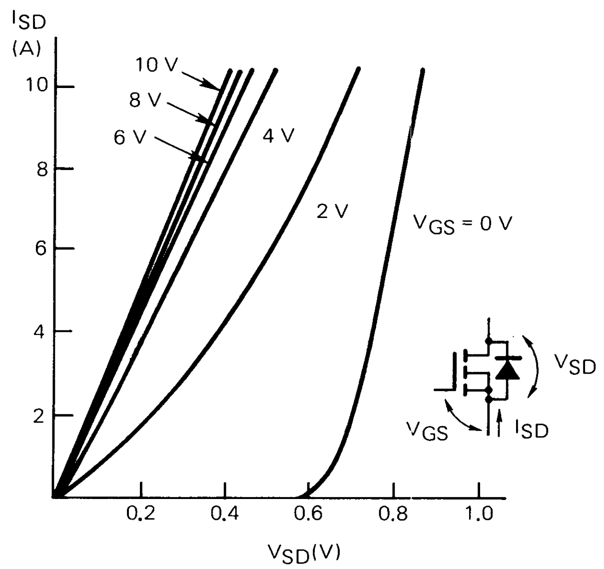

Fig. 3(b) I_{SD} Versus V_{SD} Characteristics of 2SK817

4. Stepping Motor driven circuit

Figure 4 shows a stepping motor driven circuit using the power MOS FET Array μPA1572H. In this kind of application, solenoid driven circuit is controlled mainly by 5 V power IC, so in case of using one bipolar transistor (especially darlington transistor), it needs another for lack of DC current gain h_{FE}. On the other hand, as Figure 4 shows, each 4 V gate driven power MOS FET through one gate input resistor enables control IC to drive directly solenoid driven circuit.

Consequently, 4 V gate driven power MOS FET is capable of reducing installation space and power dissipation of a driven circuit and a main circuit.

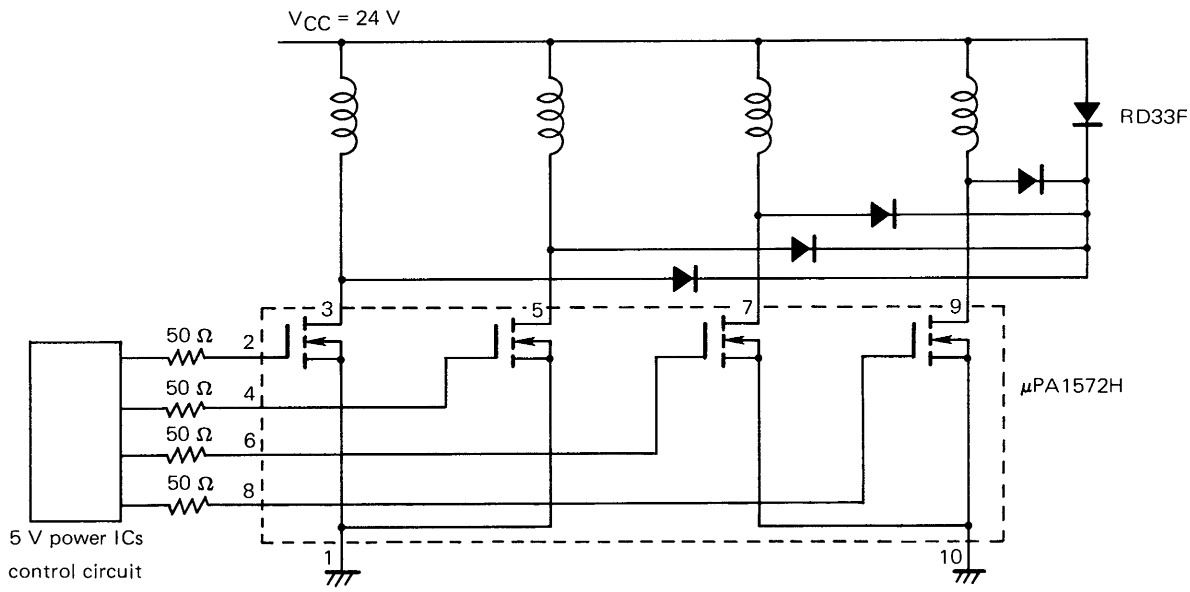

Fig. 4 Stepping motor driven circuit

5. Pulse Width Modulation (PWM) Motor Control Circuit

Figure 5 shows a PWM motor control circuit of H bridge type using 4 power MOS FETs, which is an example of forward-backward drive control circuit.

In figure 5, power MOS FETs, Q_3 and Q_4 control PWM and power MOS FETs, Q_1 and Q_2, connected with high electrical potential use a drive circuit made up of power MOS FETs, Q_5 and Q_6, zener diode and so on.

If forward and backward revolutions of motor are A and B directions respectively, current flows as follows.

In case of forward revolution of motor Q_1 is on and Q_4 is turned on and off at high frequency, current flows Q_1 to Q_4 since current flows through inverse diode of Q_2 when Q_4 is turned off.

In the same way, in case of backward revolution of motor-Q_2 is on and Q_3 is turned on and off at high frequency, current flows Q_2 to Q_3 since current flows through inverse diode of Q_1.

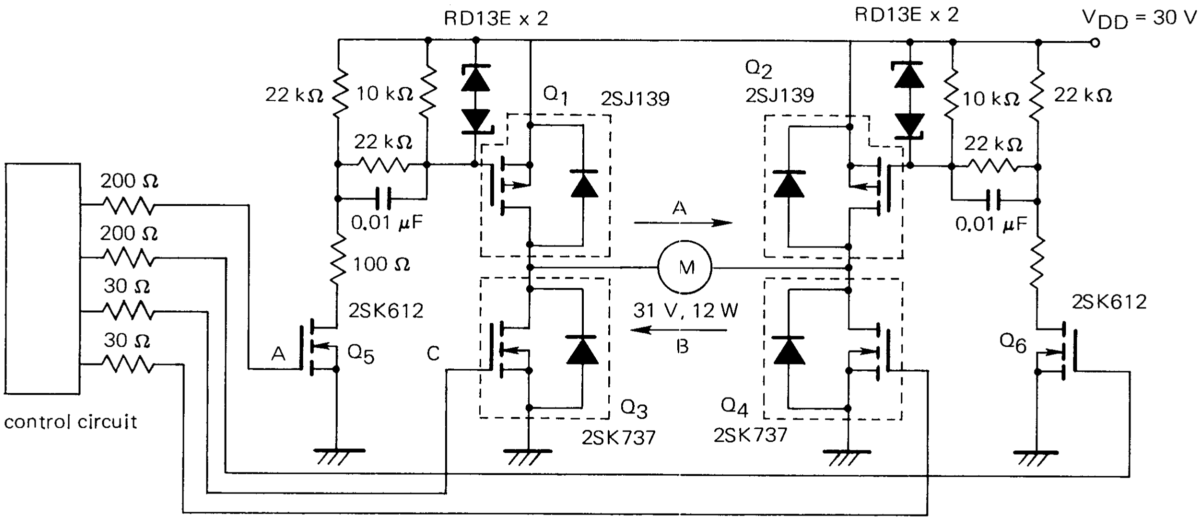

Fig. 5 PWM motor control circuit

6. Analog Switching Circuit

Figure 6 shows analog switch circuit of AC signal.

This application positively makes use of the resistance characteristics of power MOS FET, caused by gate forward bias whether drain-to-source voltage is positive or negative.

In case of 0 V gate bias, forward direction between drain and source is off and backward direction between them is equal to forward voltage drop characteristics of general silicon diode.

Consequently, in case that signal voltage is lower than forward voltage of diode, the impedance between them becomes high.

In case of gate forward bias, on-state resistance of power MOS FET between drain and source in both directions becomes low and the circuit is turned on. In this way, it is capable of switching in this circuit.

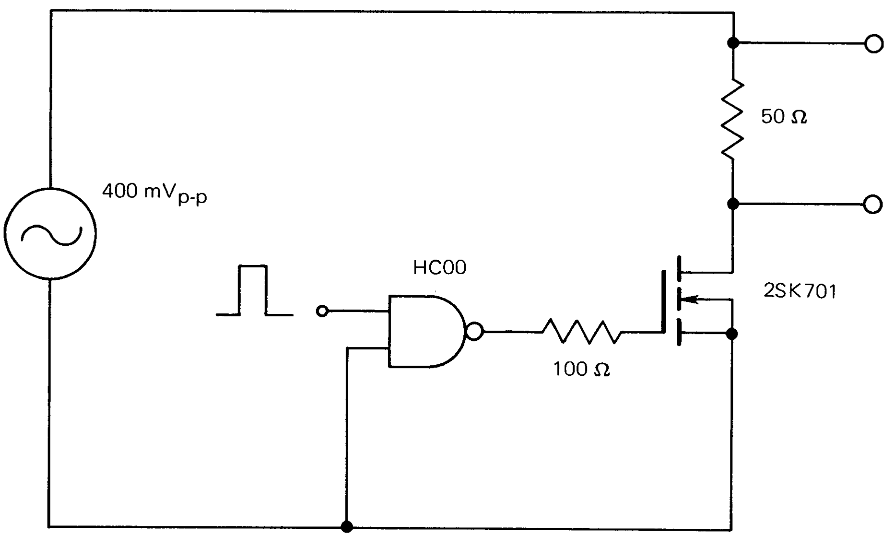

Fig. 6 Analog switches circuit

7. AC Power Control I

Figure 7 shows thermal control circuit using thermistor. As compared with the conventional AC power control circuit using TRIACs, this application circuit using power MOS FETs has such advantageous characteristics as to make current flow in the forward and backward directions and drive power very small.

In case that thermistor temperature is lower than the set-up temperature in this circuit, comparator out put is high and power MOS FETs, Q_1 and Q_2 are biased between gate and source.

If A and B sides in AC power are positive and negative cycles, respectively in case of gate-to-source bias, current flows from AC power, Q_1's drain, Q_1's source to Q_2's source (inverse diode) load.

On the other hand, if A and B sides are negative and positive cycles, respectivity, current flows is opposite to the above case. And in case that thermistor temperature reaches the set-up temperature, comparator out put is low and Q_1 and Q_2 are turned off.

In the above-mentioned way, this application circuit controls the definite temperature.

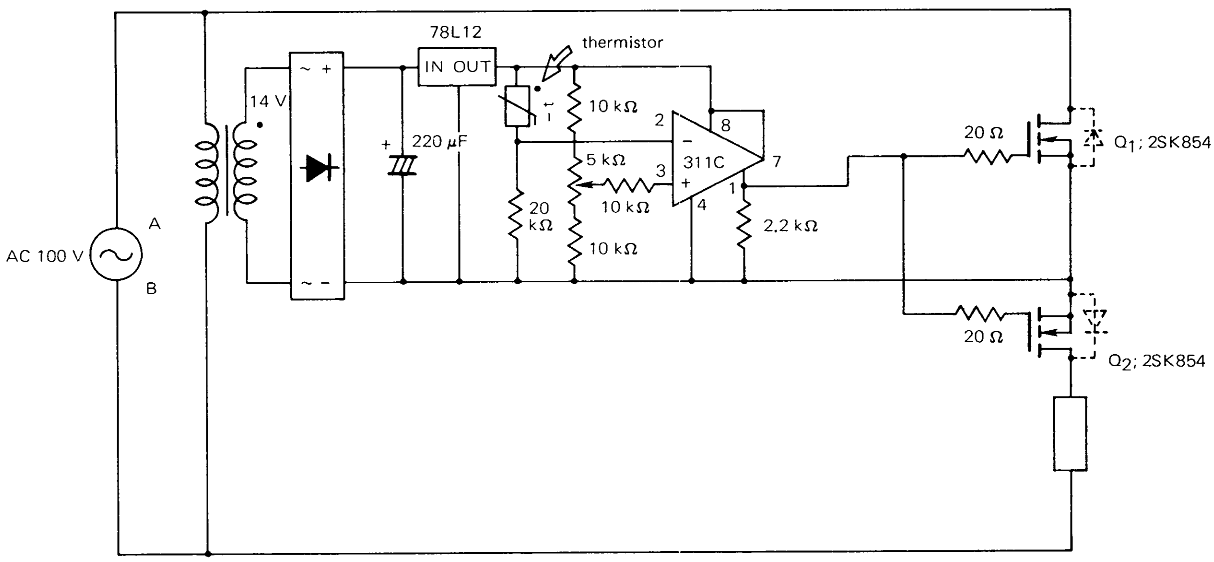

Fig. 7 AC Power Control I

8. AC Power Control II

Figure 8 shows temperature control circuit using the phase control which AC power control has of its own. This application circuit controls temperature by changing conduction phase of each half cycle of AC.

In case that the AC power control input is 100 V like figure 8, the power MOS FET that drain-to-source voltage is 400 V rating, is made use of. So this application circuit is effective when on-state resistance between drain and source is bigger and load is comparatively lower.

In case that AC power voltage is also low, power MOS FET is superior to TRIAC in point of power dissipation.

1) Power MOS FET is a voltage drive type and is capable of being directly driven by control IC as Figure 2 shows, and so it simplifies a drive circuit and reduces drive power.

2) Power MOS FET is a mjority-carrier device and no effect of storage, and so it is capable of high speed switching.

3) Power MOS FET suffers no secondary breakdown and can make parallel operation easy because $R_{DS(on)}$– drain to source on-state resistance, has a positive temperature coefficient.

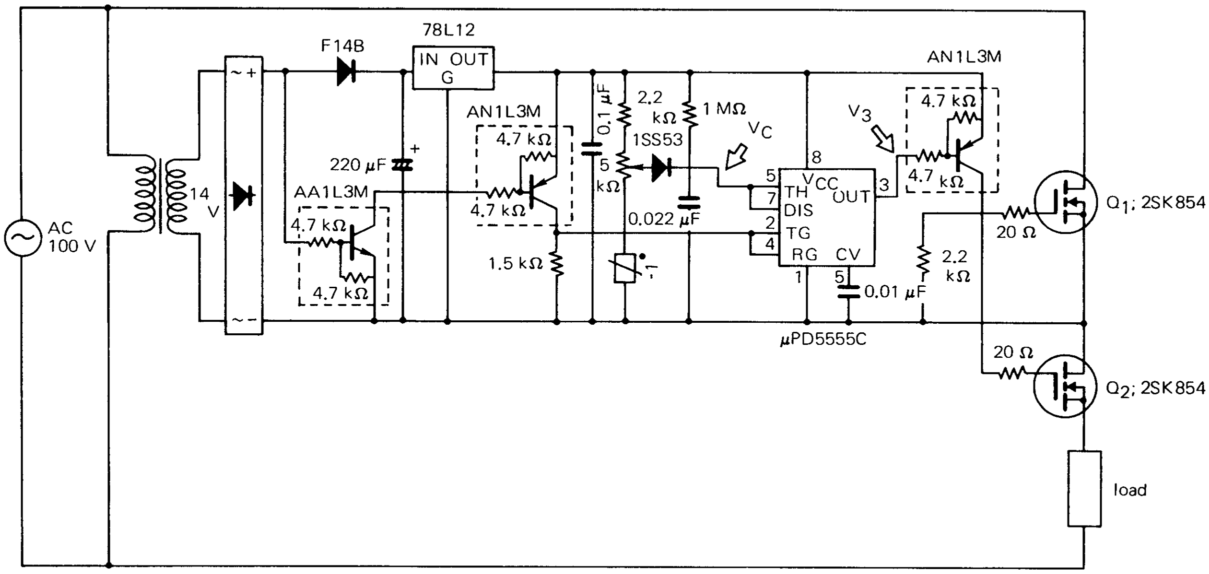

Fig. 8 Temperature control circuit using phase control

9. PWM Power Control Cicuit

Fig. 9 shows Power Control Circuit using Power MOS FET. This application is a dimmer function duty control circuit where duty cycle of Power MOS FET is adjusted by variable capacitor VR, can be adjusted 1 % through 99 % with the constant CR.

The following is an explanation on movement principal shown in Fig. 9. Capacitor C_1 is charged from VR_1 and R_4. This charge current flows from the base (B) to the emitter (E) and Q_3 is turned-on. Collector to emitter voltage of Q_3 is saturated by Q_3 turn-on and at the same time Q_1 is off state. The partial voltage, which is generated by dividing CD total power supply with R_1 and R_2, is supplied to the gate of PUT (Q_2). If voltage C_1 is higher than the total votage of gate votage of Q_2+ off-set votage V_T of PUT (Q_2), Q_2 is turned-on and this makes the capacitor C discharge into the closed circuit $C_1 \rightarrow C_2 \rightarrow VR_2 \rightarrow R_5 \rightarrow C_1$.

At this time, base to emitter voltage of Q_3 is reverse-based and is turned off, collector to emitter voltage of Q_4 rises, Q_4 is turned-on immediately because current flows into the base of Q_4 and Q_2 is turned off. This causes the discharge current flowing from C_1 to Q_4, E, VR_2, R_5, C_1.

On the other hand, Q_1 is turned-off because Q_3 is turned-off, and current flows to load lamp. When electrical charge of C_1 is discharged and base to emitter voltage of Q_3 is forward biased again, Q_3 is turned on, Q_1 is turned-off and Q_2 is turn-off as R_1 is connected to high electrical potential and charge of C is started. The same movement as the above will be repeated after that.

R_b is put for the reduction of MOS FET turn-off time. Fig. 10 is an example power control circuit with P-channel power MOS FET. Movement principal is same as Fig. 9 except that on-off states of MOS FET will be replaced by turns because the polarity of it is positive.

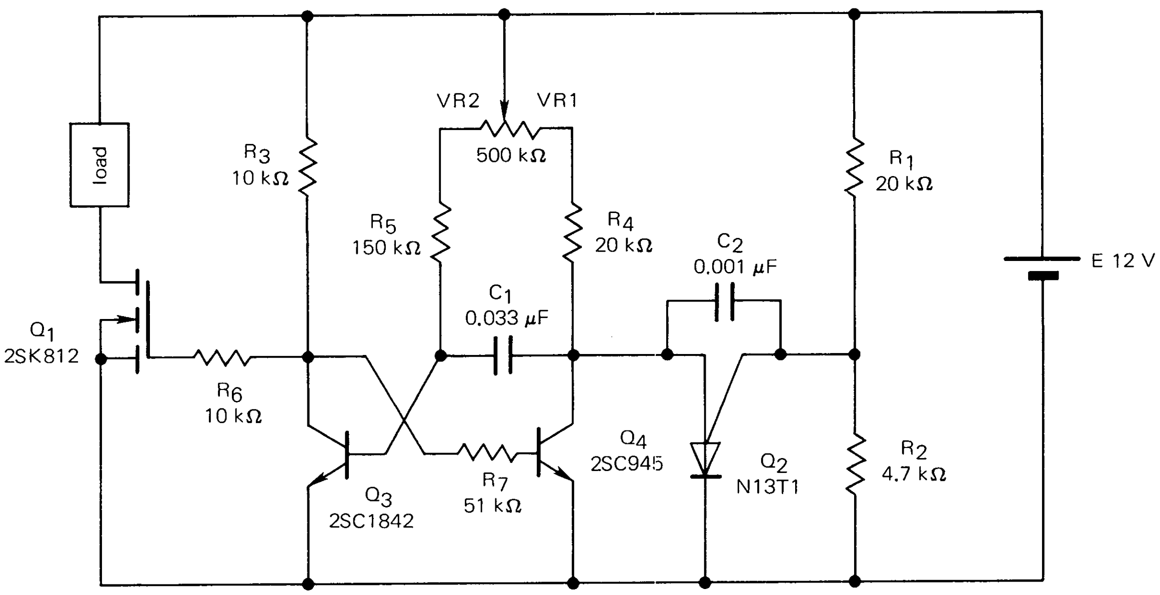

Fig. 9 PWM Power Control Circuit using Power MOS FET

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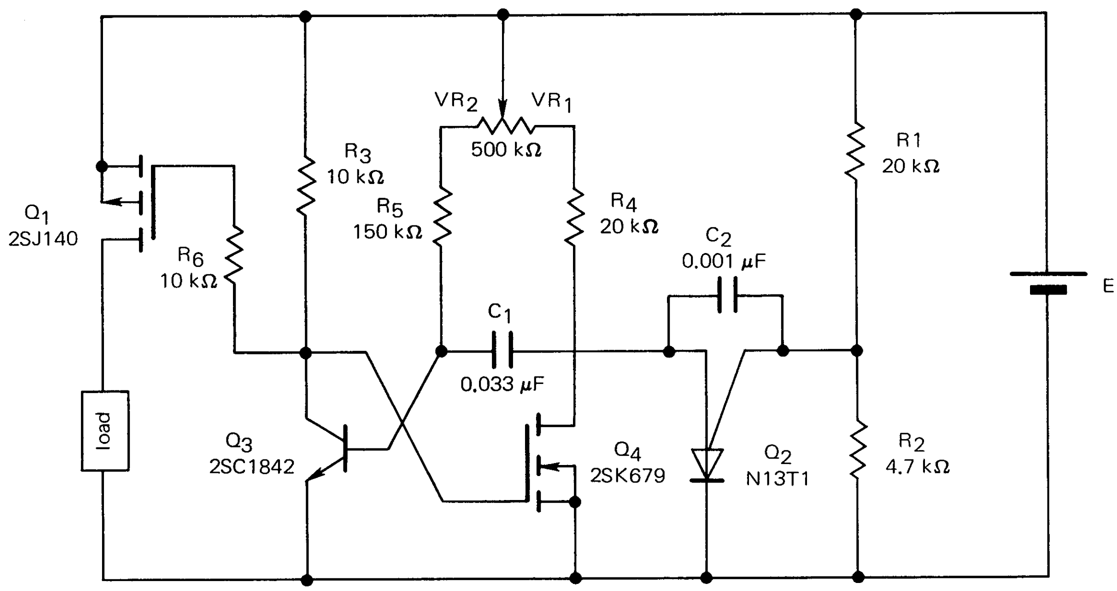


Fig. 10 PWM Power Control Circuit using Power MOS FET

Photo. 2 Drain to Source Voltage Waveform of Power MOS FET Q_1 at Duty Cycle ≒ 20 %

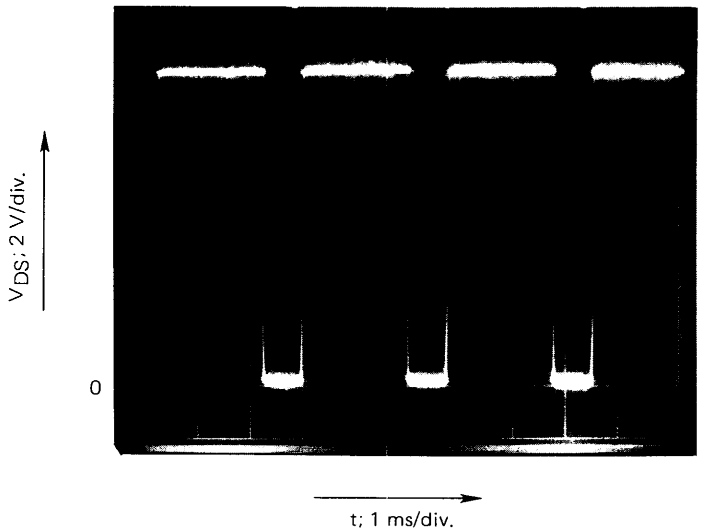
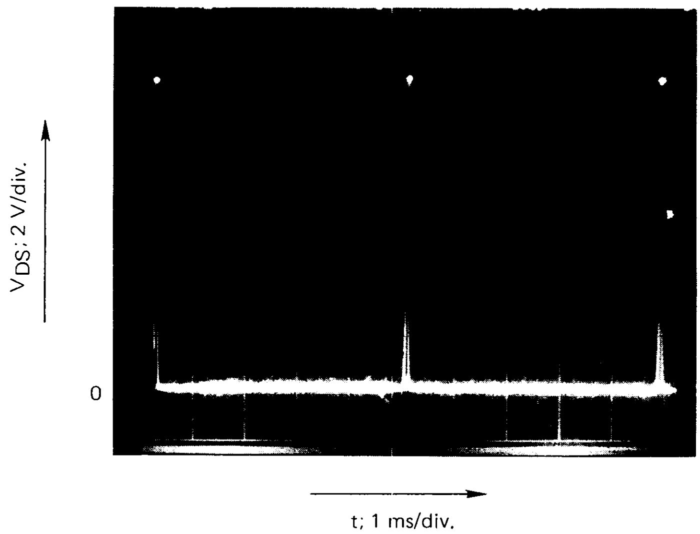


Photo. 3 Drain to Source Voltage Waveform of Power MOS FET Q_1 at Duty Cycle ≒ 98 %



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