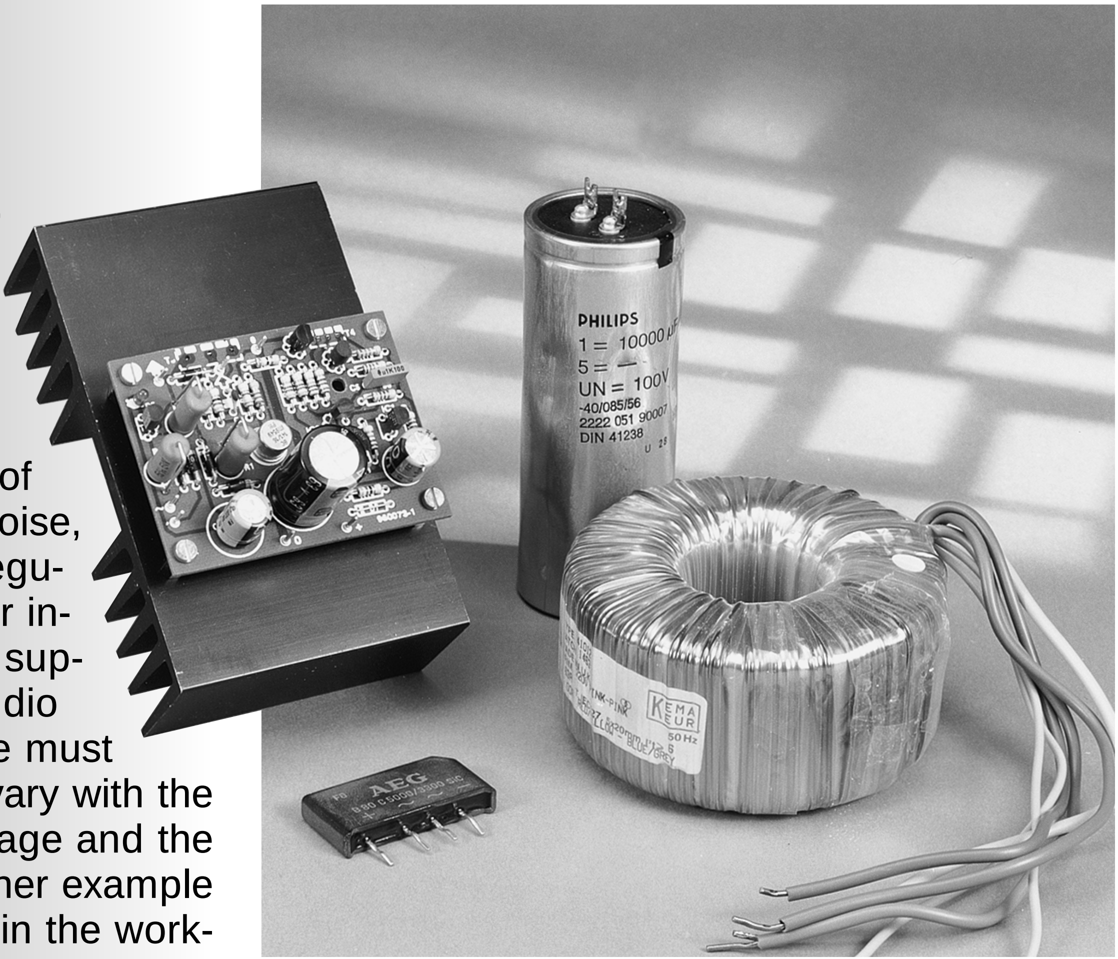
Contents

active power buffer

with temperature monitor



Frequently, a direct voltage is required in a circuit that must be free of hum and noise, but not regulated. For instance, the supply to an audio output stage must be able to vary with the mains voltage and the load. Another example is when in the workshop a variable-ratio transformer (variac) is to produce a well-filtered direct voltage with good loading capacity for general purposes.

Design by W. Steimle

The hum emanating from an unregulated power supply is normally caused by too high a current drain or too small a reservoir capacitor. Enlarging the capacitor is often the simplest, but not always the most effective, way of dealing with the problem. Hum is the manifestation of a ripple on the output voltage and it is best to suppress this in an active manner.

The circuit diagram in **Figure 1** looks like that of a conventional series regulator, but has no regulating amplifier with control comparator. Therefore, the output voltage automatically adapts itself in accordance with the input alternating voltage and the current through the load. Consequently, the entire hum voltage is applied to the collector-emitter junction of darlington transistor T_3. The advantage of such an arrangement lies in a drastic reduction of the maximum dissipated power (at the highest mains voltage).

The lower part of the figure is a temperature monitor in which T_4 is the sensor. If this transistor detects an overtemperature, the monitor circuit pulls the base of driver T_2, and thus that of T_3, to ground. This effectively cuts off the output current, so that no more power is dissipated.

1

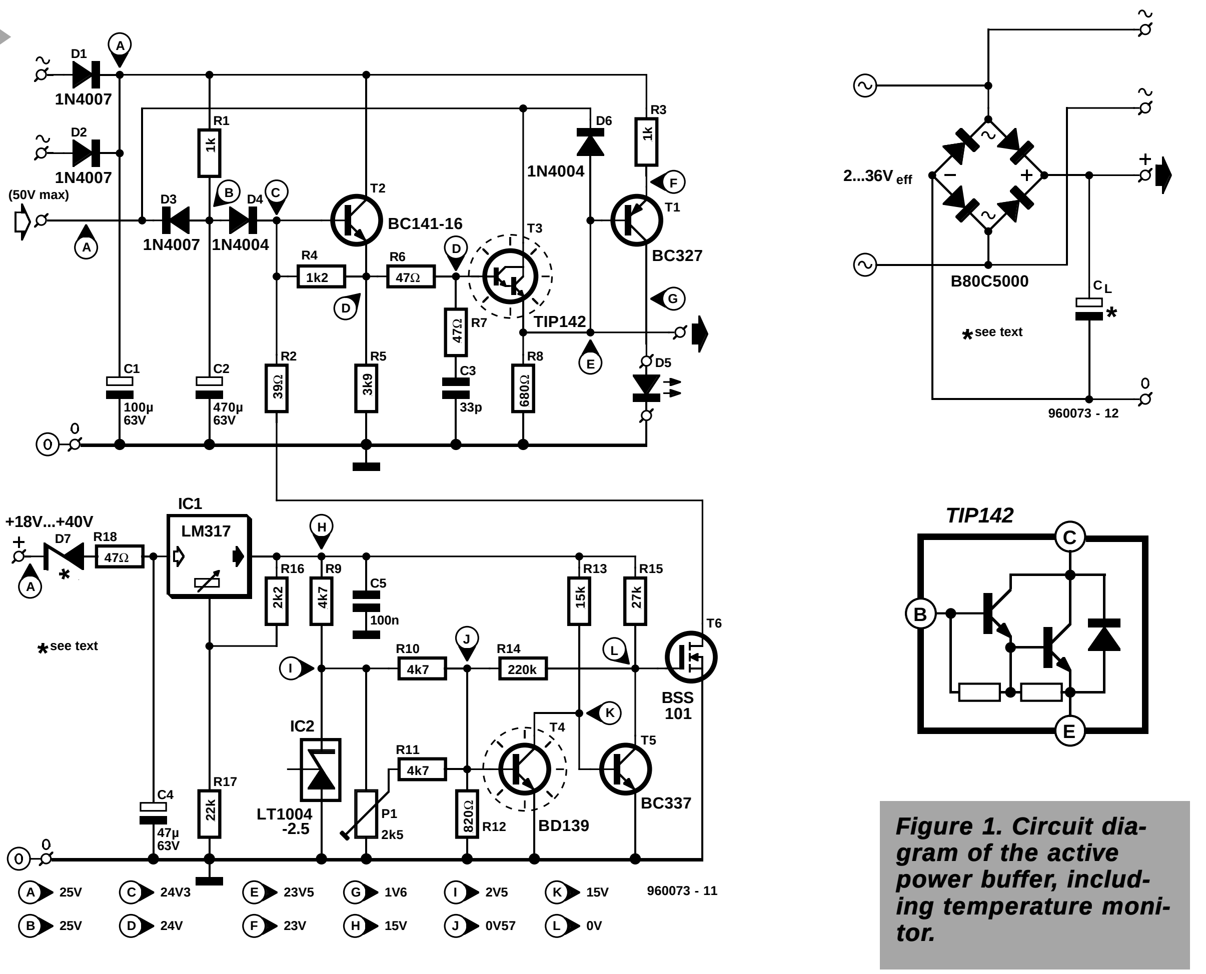


Figure 1. Circuit diagram of the active power buffer, including temperature monitor.

CIRCUIT DESCRIPTION

The circuit is arranged so that the power section (upper part of the figure) and the temperature monitor have their own rectifier. That for the monitor is the bridge rectifier, shunted by reservoir capacitor C_L, while D_1 and D_2 serve the power section.

Whereas the potential across C_L has a ripple whose level depends on the load current, the voltages across C_1 and C_2 are virtually free of ripple, since the load is small. The potential across C_1 is about equal to the peak value of the alternating voltage applied to the bridge rectifier. The voltage across C_2 depends on the minimum level across C_L, $U_{o(min)}$, because it is pulled down by D_3 twice in each mains period to $U_{o(min)} + U_{D3}$. The potential across C_2, U_{C2}, determines the output voltage, which is about $U_{C2}–4U_{D3}$.

Diode D_4 is necessary to ensure that U_{CE} of emitter follower T_2 retains a nominal value when the potential across C_1 is a minimum. Resistors R_4 and R_5 ensure that the direct current through T_4 is not too dependent on the current amplification of the transistor and the load current.

Resistor R_1 provides the charging current for C_2, which must, of course, always be greater than the current through D_4 and the base current of T_2. Since the drop across R_1 increases the dissipation of T_3, the resistor should be kept as small as possible. It should be not too small, however, because at large load currents it determines the ripple on U_{C2}. Its specified value is a compromise between these conflicting requirements.

Since the base of T_3 is fed from the inductive output of T_2, resistor R_6 is necessary to obviate any tendency of the darlington to oscillate. Note that R_7 and C_3 already tend to make the reactance more resistive.

Resistor R_8 provides a minimum load for the circuit.

Resistor R_5 prevents driver T_2 from switching off during the quiescent state when T_3 draws only a tiny base current.

Transistor T_1 draws a current through D_5, which is more or less directly proportional to the peak hum voltage and inversely proportional to the value of R_3. This means that the

2

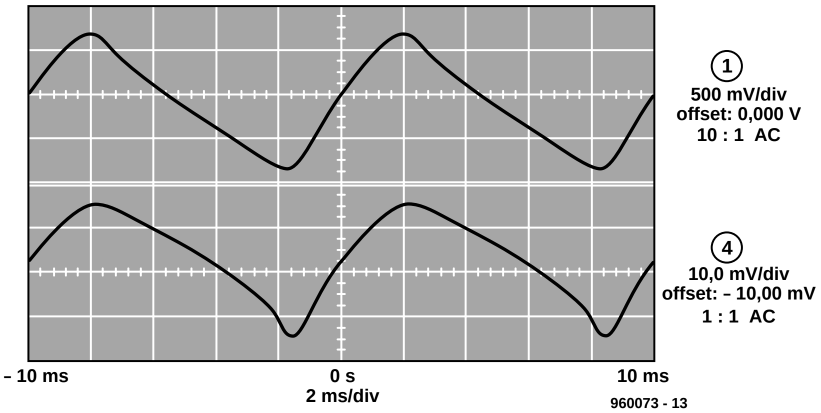


Figure 2. A 100 Hz hum voltage and the direct voltage at the output that depends on the load current; input alternating voltage is 20.7 V.

3

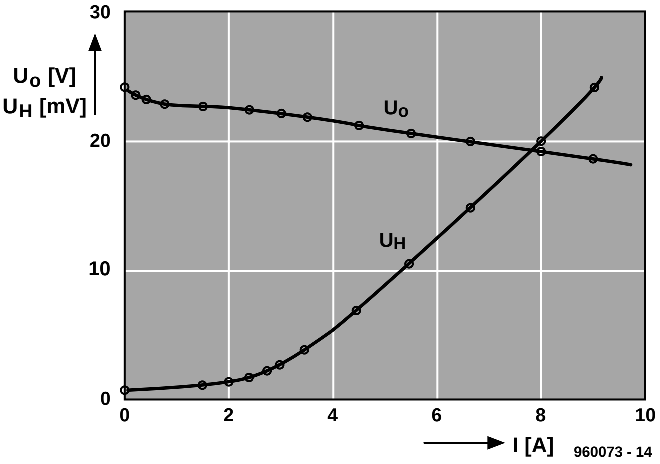


Figure 3. Hum voltage vs time at the input and at the output of the circuit.

brightness of the LED increases with rising load current.

Diode D_6 comes into action only when, for instance, the circuit is being used to charge a battery and the mains fails. The diode then prevents too high a reverse-bias voltage at the base-emitter junctions of T_2 and T_3.

The output resistance, R_o, of the circuit depends in the first instance on the value of C_L and the peak-to-peak value of the hum voltage, $U_{H(pp)}$, across this capacitor:

$$R_o \approx U_{H(pp)}/I_o \approx 1/2fC_L,$$

where f is the mains frequency. Thus, if C_L = 10 mF, R_o = 1 Ω.

The residual hum voltage at the output depends on load current I_o. This is shown diagrammatically in **Figure 2**, which assumes an output voltage of 24 V. When the load current is 10 A, hum suppression is about 30 dB. Note that the frequency of U_H is 100 Hz. Figure 2 also shows the relationship between U_o and I_o. From this it will be seen that R_o = 0.3 Ω.

These measurements were carried out with the input alternating voltage held constant at 20.7 V. In practice, this voltage drops somewhat owing to the internal resistance of the transformer.

Figure 3 shows the hum voltage at the input and output. Note that the hum suppression at peak-to-peak values is about 50, that is, 34 dB, or a little better than previously.

If the average direct voltage at T_3 is made equal to half the hum voltage, the dissipated power, P, is

$$P = U_a \cdot I_o = I_o^2/4fC_L.$$

Thus, when I_o = 10 A and C_L = 10 mF, the power dissipation is 50 W. Note that this value is independent of the output voltage.

TEMPERATURE MONITOR

For input voltages greater than about 6 V, the circuit is not proof against sustained short-circuits.

It has, however, a temperature monitor which arranges for the load to be disconnected when the temperature rises above a preset level. This arrangement is particularly sensible for occasions when, for instance, the present circuit is used in conjunction with a variac for various purposes when an unwanted overload can happen all too easily.

The sensor is a Type BD139 transistor, which should be mounted on a suitable heat sink. The sensor action is effected by the temperature dependence of the base-emitter voltage, which is easily computed. The sensor and T_5 form a Schmitt trigger with temperature-dependent threshold and hysteresis.

The base-emitter voltage of T_4 is held constant by IC_2 at a value set with P_1, at which the monitor comes into action when the temperature of the heat sink reaches 85–90 °C. When that happens, T_6 pulls the base of T_2 to ground via R_2, whereupon T_3 is cut off and the output is open-circuited.

Power for the monitor circuit is derived from a mains adaptor that must provide at least 18 V. It may also be taken from the + terminal of C_L if the potential across this capacitor lies between 18 V and 40 V. If it is higher than 40 V, it is pulled to this value by D_7. The rating of this zener diode must be such that the voltage at the input of IC_1 remains below 40 V when U_{CL} is a maximum and above 18 V when U_{CL} is a minimum.

CONSTRUCTION

The circuit complete with temperature monitor is best built on the printed-circuit board shown in **Figure 4** (which unfortunately is not available ready made). The two sections of the circuit are linked on the board by the common earth track at the centre and the connection from T_6 to the base of T_2 via R_2. If this resistor is omitted, the two sections are completely isolated from one another (apart from the common earth track).

If D_7 is not used, it should be replaced by a wire bridge.

Note that T_3 and T_4 are fitted at the track side of the board. When the board is fitted on to the heat sink as in **Figure 5**, these transistors must be fitted on to the heat sink with the aid of insulating washers, screws and nuts. Two holes are provided in the board near T_2 and T_5 to allow access to the relevant screws.

Connect the ~ terminals from the bridge rectifier to the relevant terminals on the board via light-duty insulated circuit wire, and the + and 0 terminals to the relevant terminals on the board by medium-duty insulated circuit wire.

The buffered output is available at the emitter terminal of T_3.

INITIAL TEST

The circuit may be tested by checking whether the voltages measured at various points indicated in Figure 1 coincide with the values shown in that figure. The values were measured in the prototype with an input voltage of 25 V and an open-circuit output.

SETTING UP

The temperature at which the monitor switches off the output is set with P_1. This temperature is determined by the heat resistance of the heat sink on which T_3 is fitted. If this is 1.8 K W^{-1}, for instance, and the output power is 40 W, the temperature of the heat sink is 1.8 × 40 = 72 K with respect to the ambient temperature. The temperature of the power transistor itself is another 40 K above this, so that, when the ambient temperature is 25 °C, it reaches 137 °C. The maximum permissible temperature of the TIP142 is 150 °C.

Set P_1 fully anticlockwise and load the circuit with a power resistor of 0.5 Ω, rated at ≥ 32 W and set the input voltage derived from a variac to such a value that the output current is 8 A (maximum current through the TIP142 is 10 A). If only a fixed alternating voltage is available as input, the load resistance should be chosen to cause a current of about 8 A to flow through it.
The voltage at the power transistor depends on the value of C_L, and it is well known that the tolerances of electrolytic capacitors vary widely. Therefore, it is better to measure the collector-emitter voltage and multiply this by the current to arrive at the dissipated power, which should be about 40 W. At this power, the LED should light.

Parts list

Resistors:
R_1, R_3 = 1 kΩ, 5 W
R_2 = 39 Ω
R_4 = 1.2 kΩ
R_5 = 3.9 kΩ
R_6, R_7, R_{18} = 47 Ω
R_8 = 680 Ω, 5 W
R_9–R_{11} = 4.7 kΩ
R_{12} = 820 Ω
R_{13} = 15 kΩ
R_{14} = 220 kΩ
R_{15} = 27 kΩ
R_{16} = 2.2 kΩ
R_{17} = 22 kΩ
P_1 = 2.5 kΩ preset

Capacitors:
C_1 = 100 µF, 63 V, upright
C_2 = 470 µF, 63 V, upright
C_3 = 33 pF
C_4 = 47 µF, 63 V, upright
C_5 = 100 nF

Semiconductors:
D_1–D_3 = 1N4007
D_4, D_6 = 1N4004
D_5 = LED, high-efficiency, red
D_7 = see text
T_1 = BC327
T_2 = BC141-16
T_3 = TIP142
T_4 = BD139
T_5 = BC337
T_6 = BSS101 (Siemens)

Integrated circuits:
IC_1 = LM317LZ (National Semiconductor)
IC_2 = LT1004-2.5 (Linear Technology) or LM336-2.5 (National Semiconductor)

Miscellaneous:
Heat sink 1.8 K W^{-1}
Insulating washers, screws and nuts for T_3 and T_4

Wait about 30 minutes, after which the heat sink temperature should be about 72 K higher than the ambient temperature (as computed earlier). It is, of course, better to measure the temperature, but this presupposes that a suitable thermometer is available.

When the stated temperature has been reached, turn the wiper of P_1 carefully clockwise until the LED lights brightest. The monitor then comes into action: the current is cut off and the temperature drops.

Wait a while for the temperature to reach a lower value, when the monitor should be deactivated, and an output current flows again.

Increase the power dissipation slightly and repeat the foregoing. In this way, average cut-off and switch-on temperatures will be set.

[960073]

4

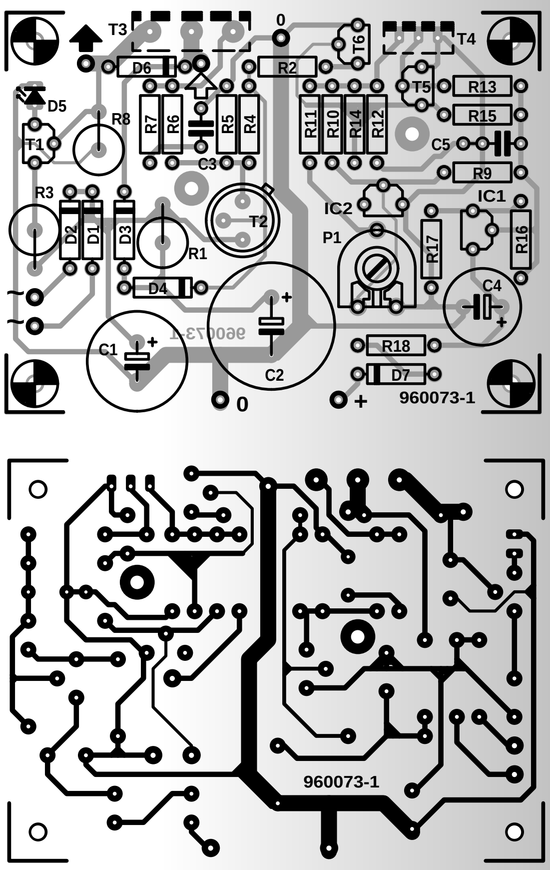


Figure 4. The printed-circuit board for the active power buffer, including temperature monitor.

5

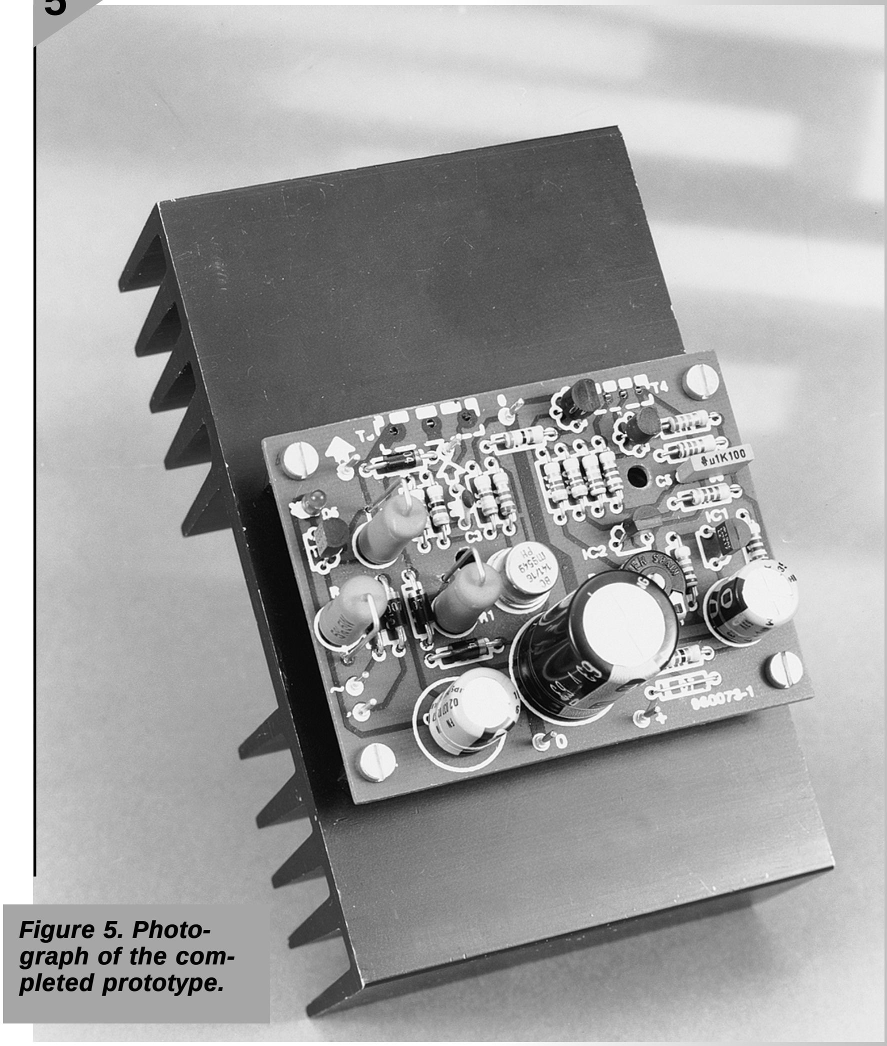


Figure 5. Photograph of the completed prototype.