SURGE SUPPRESSOR

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It is an annoying but generally accepted fact that much mains-operated equipment produces surges and other interference on the mains. But we do not have to put up with clicking noises from AF equipment as the refrigerator switches on, or a computer that stops working when the lights are switched on. All that is needed to prevent these irritating effects is a good-quality mains filter.

Ideally, any mains outlet supplies an alternating voltage of a root-mean-square (rms) value and a frequency specified by the national (or local) electricity supplier (in the larger part of the UK, these values are 240 V_{rms} and 50 Hz respectively). In practice, however, this is hardly ever so. In not a few cases, the mains voltage is occasionally corrupted by high-frequency signals, data-bursts, brief fluctuations, surges and dips.

Although mains signalling is a well-defined area*, some types of mains intercom operating at carrier frequencies of 100 kHz and up are notorious sources of interference. Pulse-like interference often emanates from dimmer circuits, switch-mode power supplies in computers and defective or poorly decoupled household equipment like coffee machines and refrigerators.

In some countries, the electricity suppliers themselves use the mains lines to convey control information for normal/reduced rate switching of domestic power consumption meters.

To avoid problems with any equipment powered from the mains, a mains filter as the one described here must work in both directions, which means that both mains-borne interference and interference generated by the equipment must be suppressed. The filter proposed here is suitable for use with 220–240 V mains systems operating at 50 Hz.

Design considerations

The mains filter is basically a passive low-pass with a roll-off frequency of 50 Hz. Its likeness to a low-pass filter for audio applications is only superficial however since the high operating voltage and the associated considerations as regards safety govern the use of special components. In many countries, standards have been set up that define the maximum capacitor values used in the filter, often depending on whether mains-powered equipment is wall- or floor-mounted, or portable. These capacitor values are a carefully established compromise between acceptable switch-on and switch-off currents on the one hand, and the risk of electrical shock in the case of defective or improperly connected earthing on the other.

Capacitors alone can not secure the required slope steepness of the filter. The attenuation outside the pass-band is improved considerably by using one or more chokes. These come in at least three versions. In general, the choke with the highest inductance is the most effective. However, if reactive loads are powered, the voltage drop across the choke rises with inductance. In practice, this means that the filter has to be geared accurately to the load and the nature of the anticipated interference.

The simplest version is the saturation choke. When the mains is switched on, this type of inductor possesses a high inductance, which rapidly becomes smaller as the current causes the ferrite-iron core to become saturated. The interference suppression grade is nearly always specified for symmetrical (balanced) interference, that is, interference that exists between the live (L) and neutral (N) line.

The multiple-winding current-compensated toroid choke is more effective but also more expensive than the saturation type. Strong capacitive coupling between the circuit and the enclosure causes an asymmetrical current (between L/N and E) to flow into the equipment through the earth wire, and half of it back into the mains through the live or neutral line. The partial interference current causes the choke, of which the windings are inserted in the phase or neutral line, to be damped so that the magnetic fields generated in the windings cancel one another. The inductance of both chokes is small for the load current and therefore introduces a small voltage drop only.

The bar-type choke is best used for loads over 100 A that produce mainly symmetrical interference (between live and neutral). In contrast to the saturation choke, the inductance of a bar-type choke remains constant.

Practical circuit

The circuit diagram of the mains filter is given in Fig. 1. The mains voltage is applied via connector K_1. Components C_1 and R_2 form a potential divider for the on/off indicator, D_1. Capacitor C_1 dis-

* Mains signaling in the UK is subject to the provisions of British Standard BS6839. Further information on the subject may be obtained from BIMSA (BEAMA Interactive and Mains Systems Association), Leicester House, 8 Leicester Street, LONDON WC2H 7BN, Telephone: (01-437) 0678.

charges via resistor R_1 when the filter is disconnected from the mains. Diode D_2 is connected across D_1 to keep the reverse voltage across the LED within safe limits. Voltage peaks exceeding 250 V are eliminated by varistor VDR_1.

Capacitors C_2 and C_3 must be class-X2 types. Similarly, C_4 and C_5 must be class-Y types. These type codes indicate an a.c. working voltage of 250 V and apply to metallized polyester or polypropylene capacitors with good self-healing properties should arcing occur in the dielectric material. X2-class capacitors may not be used in positions where their failure would expose anybody to electric shock. Consequently, these capacitors are connected between the live and neutral lines to ensure that failure can only cause a blown fuse (in the case of a short-circuit) or reduced filter operation (in the case of an open-circuit). Both effects are annoying but not dangerous.

The requirements of the Y-type capacitors, C_4 and C_5, are more stringent (see B.S. 6201, part 3, and IEC 161). Like C_2 and

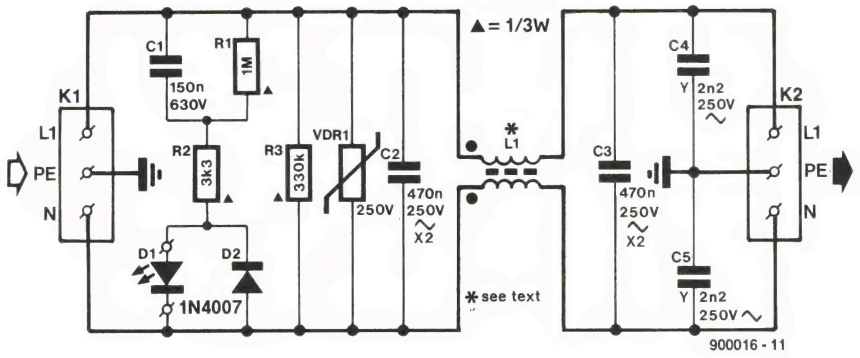


Fig. 1. Circuit diagram of the surge suppressor.

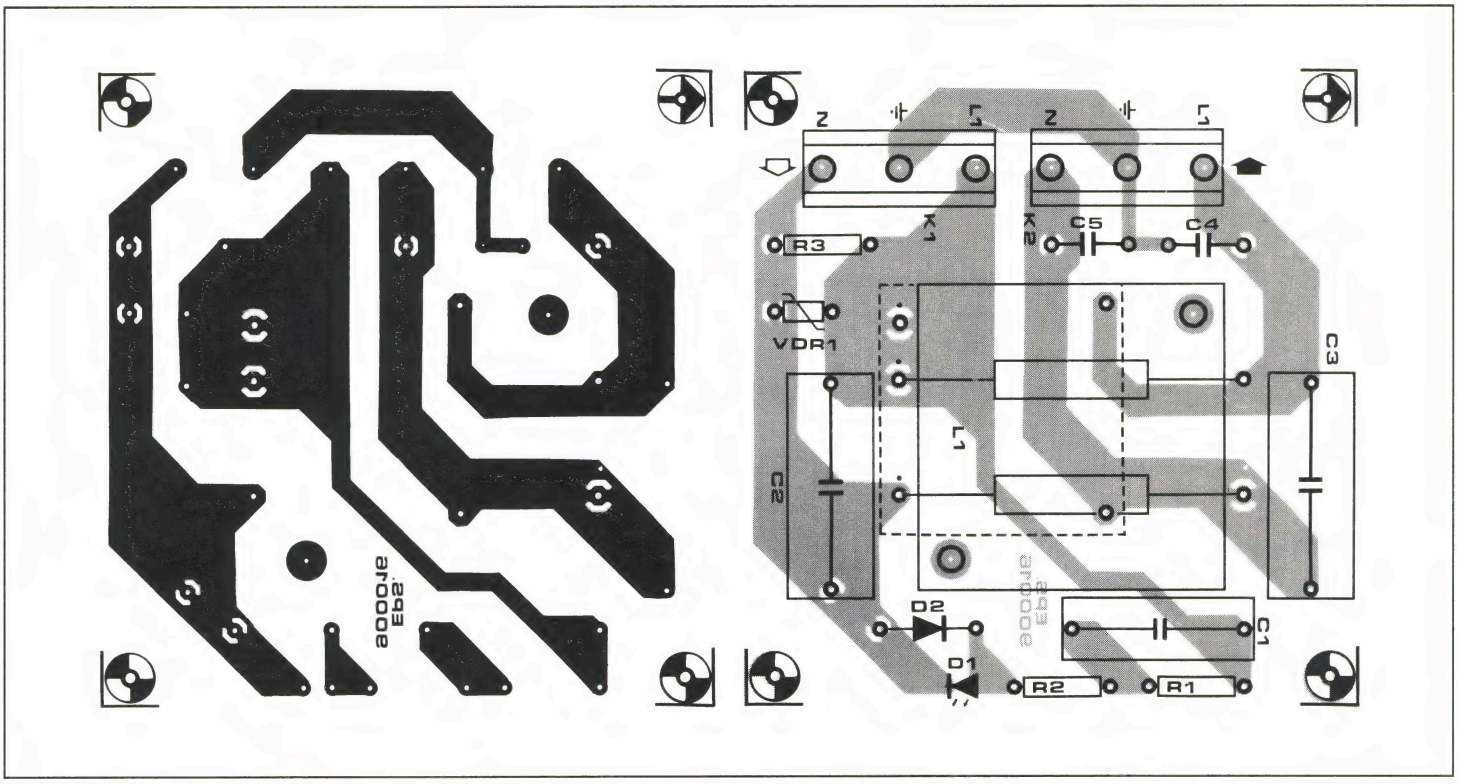


Fig. 2. Track lay-out (mirror image) and component mounting plan of the printed-circuit board for the mains filter.

COMPONENTS LIST

Resistors:
R_1 = 1M0 0.33 W
R_2 = 3k3 0.33 W
R_3 = 330k 0.33 W
VDR_1 = S10K250 [1]

Capacitors:
C_1 = 150n; 630 VDC
C_2;C_3 = 470n; 250 VAC class-X2 [2]
C_4;C_5 = 2n2; 250 VAC class-Y [3]

Semiconductors:
D_1 = LED 5 mm red
D_2 = 1N4007

Miscellaneous:
L_1 = choke 2×10 mH Type RD62-3 or 2×4 mH type RD 62-6 [4].
F_1 = fuse 2.5 A slow (for RD62-3) or 5 A slow (for RD62-6).
K_1;K_2 = 3-way PCB screw terminal block (pin distance 10 mm).
ABS enclosure 110×110×65 mm.
Panel-mount mains socket with integral fuse-holder.
Panel-mount mains receptacle.
PCB Type 900016 (not available through the Readers Services).

[1] ElectroValue Limited • 28 St Judes Road • Englefield Green • Egham • Surrey TW20 0HB. Telephone: (0784) 33603. Telex: 264475. Fax: (0784) 35216. Northern branch: 680 Burnage Lane • Manchester M19 1NA. Telephone: (061 432) 4945.

[2] e.g., RS Components stock no. 115-219.
[3] e.g., RS Components stock no. 114-496.

[4] Schaffner UK • Headley Park • Area 10 • Headley Road East • Woodley • READING RG5 4SW. Telephone: (0734) 697179.

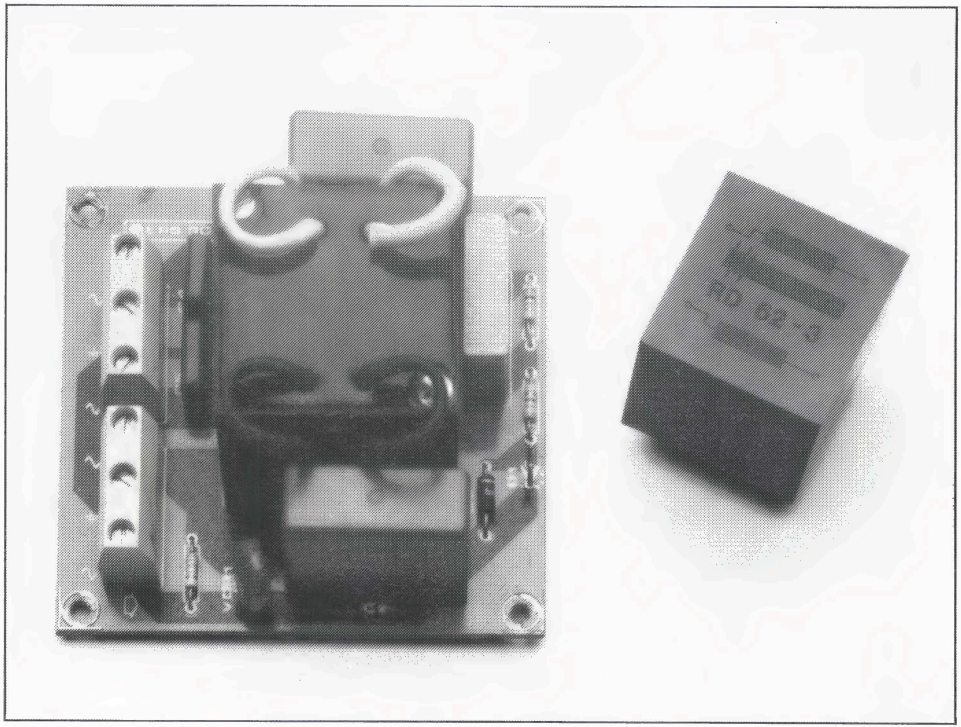
C_3, they cause degraded filter operation in the case of open-circuit failure. More importantly, however, a short-circuit in either C_4 or C_5 causes the live (L) or neutral (N) line to be connected to the protective earth line. Hence the following warning:

Never use capacitors of a different type or rating than those indicated.

The inductance in the filter is formed by a current-compensated choke. The printed-circuit board allows two different types from Schaffner to be fitted. These types differ in respect of maximum load current and inductance. The 2x10 mH inductor Type RD62-3 is rated for up to 3 A, and the 2×4 mH Type RD62-6 for up to 6 A.

Construction

For reasons of safety, the mains filter must not be constructed on any other board than that shown in Fig. 2. Construction is straightforward with the possible exception of L_1, of which the mounting depends on the type used. The larger and more expensive 6-A inductor is fitted upside-down on the PCB. The underside of the choke has four colour-marked wires. The two dark-coloured wires are the input connections (at the side of C_2 in the circuit diagram). The two light-coloured wires are the output connections (at the side of C_3 in the circuit diagram). The photograph in Fig. 3 shows the RD62-6 on the completed board.



The smaller 3-A inductor Type RD62-3 is fitted in the normal manner with the connections inserted direct into the relevant PCB holes.

Do not test the mains filter before it is fitted into the relevant equipment, or —if it is to be used for various appliances— into a separate ABS enclosure without any metal part. The prototype shown in the introductory photograph has a mains socket and a mains plug for panel mounting as used on personal computers. ■