POWER LINE MONITOR

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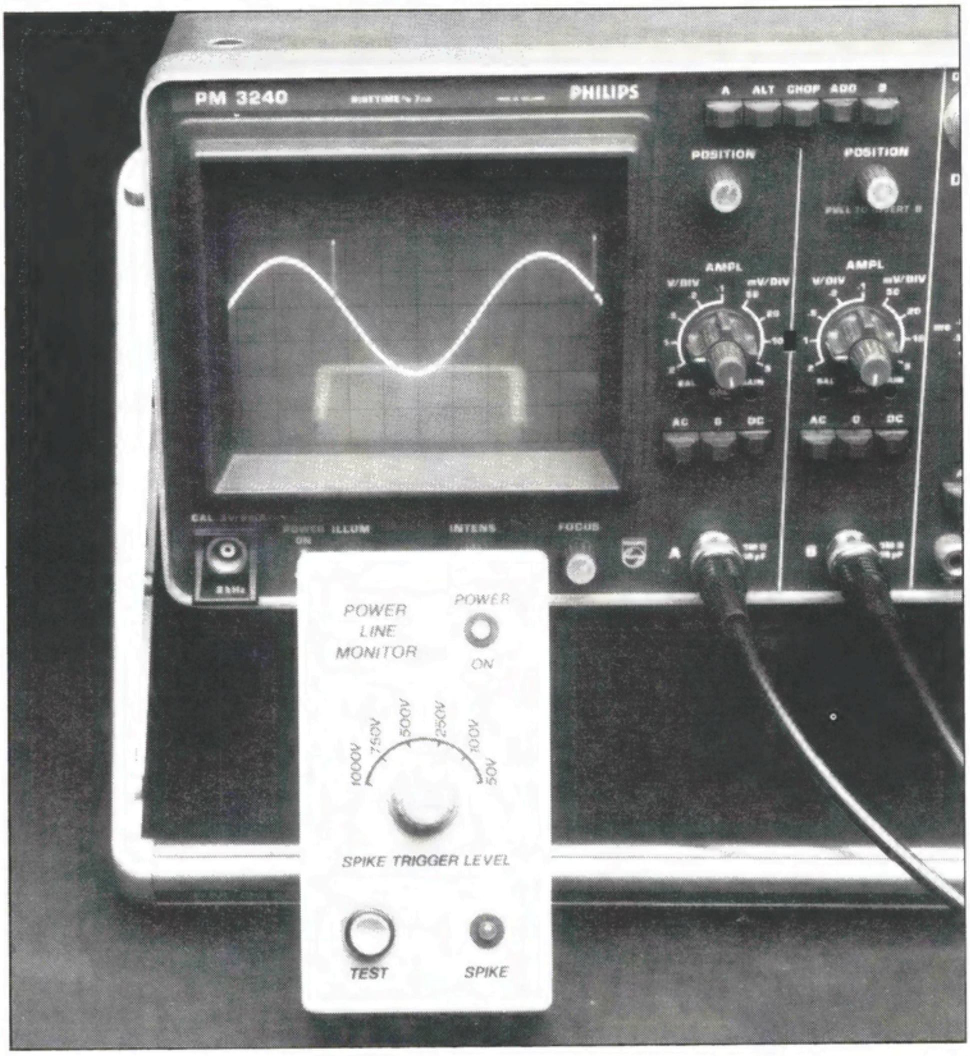
Most of us are aware that computers and other digital systems can go haywire just like that. If neither the hardware nor the software can be blamed for the hang-up, spikes on the mains voltage are the most likely cause of the trouble. The power line monitor described here enables you to determine whether or not spikes occur frequently on a particular mains outlet, and whether or not digital equipment needs to be powered via a mains filter to reduce the risk of hang-ups or total break-downs.

Sudden transient disturbances of the mains voltage are commonly referred to as surges or spikes. Since their peak voltage can exceed the normal mains voltage by hundreds of volts, it is not surprising that mains-powered equipment behaves erratically or breaks down altogether. Unfortunately, the occurrence of spikes is fairly difficult to record reliably, the reasons for which are mainly:

- the occurrence of a spike is difficult to predict;
- the voltage rise has a very short duration (typ. 10–500 ns);
- voltage peaks in excess of 1,000 V are no exception;
- the recording instrument must be connected to the mains line.

Principle of operation

The principle behind the power line monitor is shown in Fig. 1. Resistor R_9 forms a load for the rectified mains voltage. Assuming that the mains frequency is 50 Hz, the frequency of the voltage on R_9 is 100 Hz because a full-wave rectifier, D_1-D_4, is used. Spikes typically have a much higher frequency and are, therefore, readily detected with the aid of a high-pass filter, C_1-R_t, where R_t is the input resistance of the detector circuit. The 3 dB roll-off frequency of this high-pass is about 16 kHz, while its time-constant, τ, equals R_tC_1=10 µs. The function of R_9 may be less obvious in this basic circuit. Without it, however, C_1 would be charged to the peak value of the mains voltage (approx. 340 V). This would cause the diodes in the bridge rectifier to start conducting again if the mains voltage rises above this peak value. As a result, a 200-V spike during the mains zero crossing could not be detected since it would end up in the bridge rectifier. R_9 is, therefore, fitted to ensure that the voltage on C_1 follows the rectified voltage accurately. Hence, spikes are not



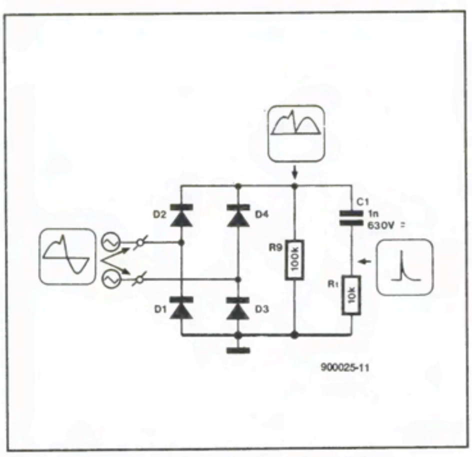


Fig. 1. Principle of spike detection.

MAIN SPECIFICATIONS

- trigger level adjustable in six steps: 50 V; 100 V; 250 V; 500 V; 1000 V
- response time: <50 ns
- potential-free detector output via opto-coupler ($U_{CE(max)}$=32 V)
- built-in mains power supply
- visual and audible spike indication

blocked by the rectifier, and they are too fast to be 'followed' by C_1. The result is that each and every spike or dip on the mains voltage appears across R_t. Dips, however, are ignored by the detector circuit.

Circuit description

Figure 2 shows the circuit diagram of the power line monitor. The mains voltage is rectified by a bridge circuit composed of four diodes Type 1N4007. This diode is used because of its peak reverse voltage specification of 1,500 V. The value of R_9 is a compromise between acceptable dissipation and sufficient loading of C_1. The high-pass filter is formed by C_1 and R_1-R_8. The minimum working voltage of C_1 must be 630 VDC since the device has on it the rectified voltage of about 340 V. The resistor ladder network, R_1-R_8, has only the spikes across it.

The ladder network and the associated rotary switch allow spikes at a certain level to be attenuated before they are applied to the trigger input of the detector, IC_{1b}, via the pole of S_1. A Type 74HCT221 dual MMV is used because of the following specifications, of which the importance is undisputed in the application circuit:

- the inputs are protected up to 2.5 kV typical;
- the input capacitance is low at 3.5 pF typical;
- the minimum width of the trigger pulse is 14 ns;
- the trigger level is accurately defined at 1.3 V, which enables a simple voltage divider to be used.

Note, however, that the actual minimum trigger pulse width is determined by the input attenuator and the stray capacitance of the input protection diodes, D_9-D_{10}, and the trigger input of IC_{1b}. This R-C combination forms a low-pass filter that causes spikes to be detected only if they are longer than 50 µs.

Monostable multivibrator (MMV) IC_{1b} is triggered when the attenuated spike voltage exceeds the trigger threshold set with S_1. On triggering, outputs Q and $\overline{Q}$ supply a 20-ms pulse. The pulse at the Q output is fed to IC_{1a}, which lengthens it to about 1 second. During this time, LED D_{11} and buzzer Bz_1 signal the occurrence of a

OPERATION AND CONTROLS

Range switch (S_1): set to expected spike level. Spikes exceeding set level are detected and indicated.

Test switch (S_2): press to test trigger function (manual trigger)

LED (D_5): on/off Indicator

LED D_{11} and buzzer Bz_1: spike indicators

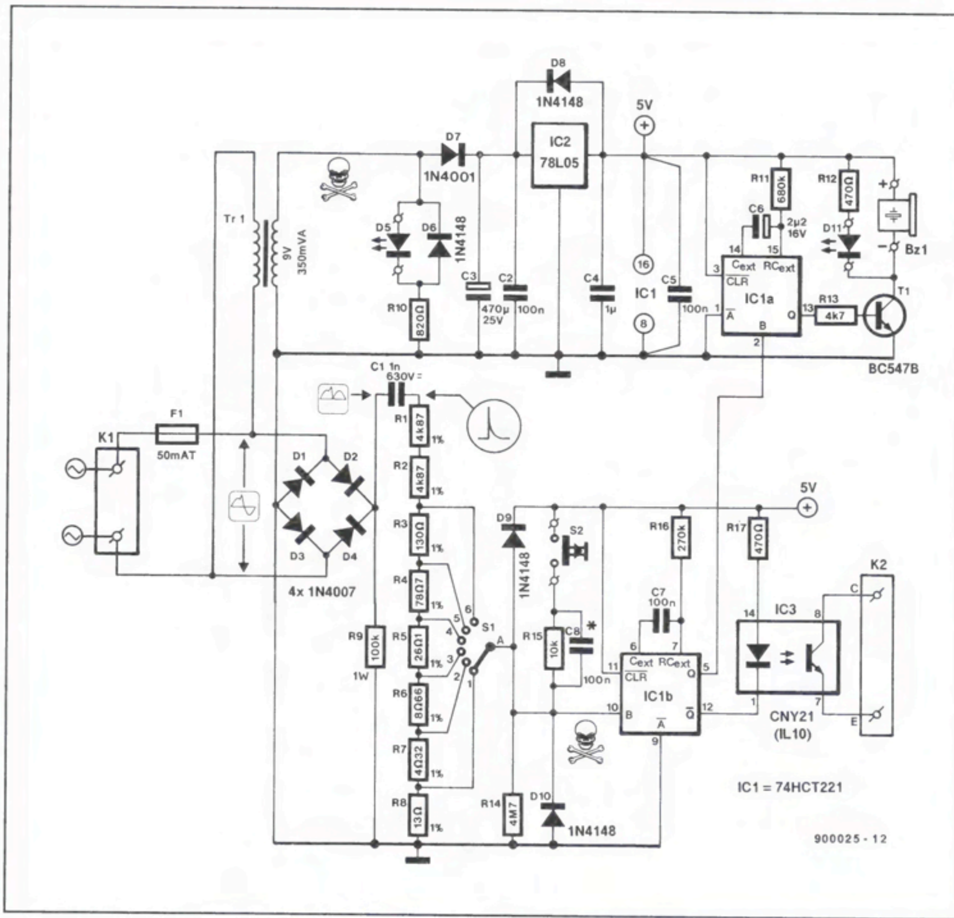


Fig. 2. Circuit diagram of the power line monitor.

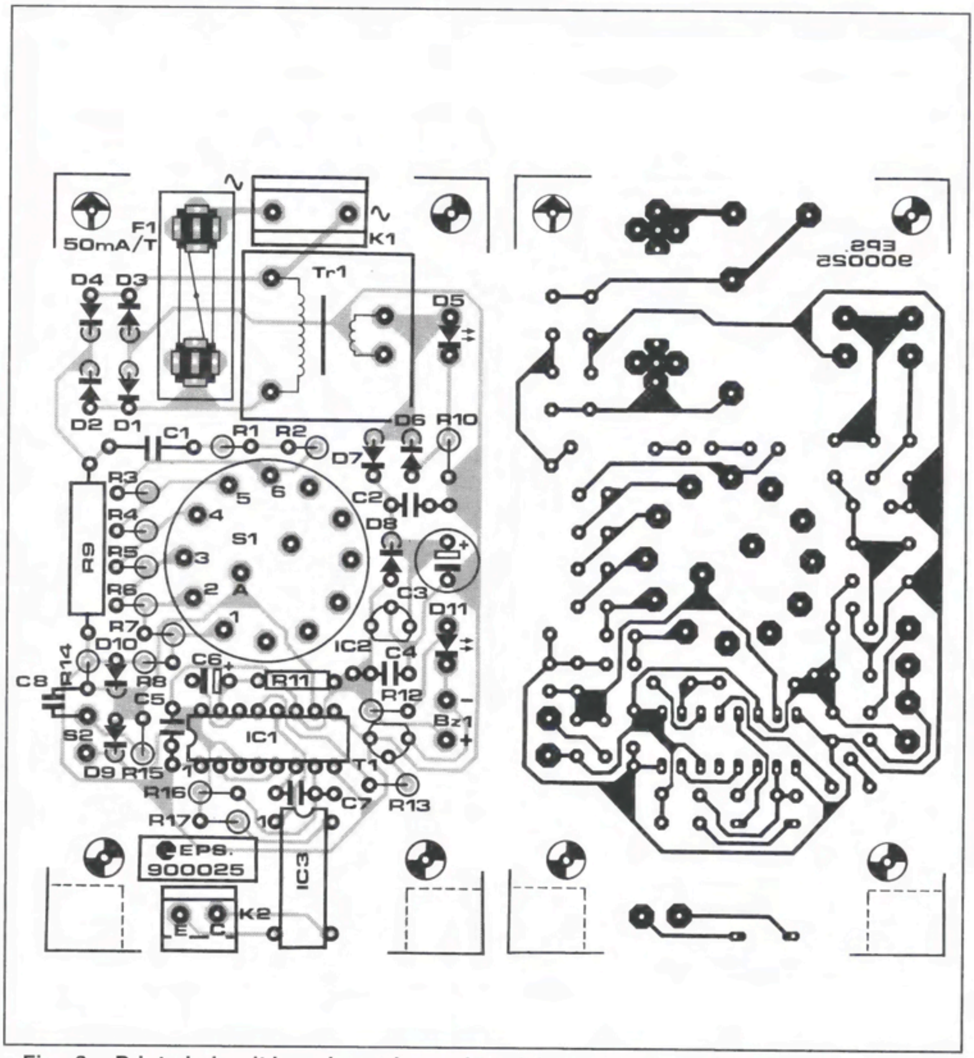


Fig. 3. Printed-circuit board overlay and track lay-out (reflected).

COMPONENTS LIST

Resistors:
R_1;R_2 = 4k87 1%
R_3 = 130Ω 1%
R_4 = 78R7 1%
R_5 = 26R1 1%
R_6 = 8Ω66 1%
R_7 = 4Ω32 1%
R_8 = 13Ω 1%
R_9 = 100k 1 W
R_{10} = 820Ω
R_{11} = 680k
R_{12};R_{17} = 470Ω
R_{13} = 4k7
R_{14} = 4M7
R_{15} = 10k
R_{16} = 270k

Capacitors:
C_1 = 1n0; 630 V
C_2;C_5;C_7 = 100n
C3 = 470μ; 25 V; radial
C_4 = 1μ0
C_6 = 2μ2; 16 V; radial
C_8 = 100n

Semiconductors:
D_1 – D_4 = 1N4007
D_5 = LED 5 mm green
D_6;D_8;D_9;D_{10} = 1N4148
D_7 = 1N4001
D_{11} = LED; 5 mm; red
T_1 = BC547B
IC_1 = 74HCT221
IC_2 = 78L05
IC_3 = CNY21 or IL10 (Siemens; Electro-Value Ltd.)

Miscellaneous:
S_1 = 2-pole 6-way rotary switch for PCB mounting; plastic spindle.
S_2 = miniature push-to-make button.
Bz_1 = 5-V active buzzer.
F_1 = fuse; 50 mA; slow; with PCB-mount holder.
Tr_1 = 9 V/0.35 VA mains transformer.
K_1 = 2-way mains-rated terminal block.
K_2 = 2-way terminal block.
ABS mains supply case; outside dimensions: 120×65×40 mm.
PCB Type 900025 (see Readers Services page).

spike. The detection circuit may be tested by pressing S_2; this causes IC_{1b} to be triggered manually.

The $\overline{Q}$ output of IC_{1b} drives an optocoupler, IC_3, to create a potential-free output, i.e., an output that is not at mains potential and, therefore, safe (within limits) for connection to other equipment. Connector K_2 may be wired to the input of, for instance, an event counter to establish the number of spikes that occur during a certain period. The output may also be used to stop a digital clock, or for other time-keeping purposes, to enable the origin of the spike to be traced. Another application is the use of a storage oscilloscope to determine when and why a particular computer broke down owing to a mains surge.

Because of the limited drive capacity of the 74HCT221, the LED in the optocoupler is not fed with its maximum current. This means that the external collector resistor for the optocoupler must not be smaller than 10 kΩ to ensure that the phototransistor is just driven into saturation.

Be sure to connect the external collector resistor and the emitter of the optocoupler to the positive supply and ground respectively of the recording equipment (whether digital or analogue), **never** to the +5 V and ground lines of the power line monitor, since these may be at mains potential.

The +5 V voltage for the power line monitor is provided by a standard power supply based on a mains transformer and a fixed-voltage regulator, IC_2. Note that the use of this supply does **not** mean that the low-voltage part of the circuit is safe to touch.

Construction and initial test

With safety in mind, it is best to construct the circuit on the printed-circuit board shown in Fig. 3. This board is mounted into a so-called power supply enclosure which is supplied complete with line and neutral pins for plugging into a mains outlet.

Capacitor C_8 is not shown on the overlay, but may be connected in parallel with R_{15} at the track side of the board. The rotary switch must be a type with a plastic shaft, and the push-button must be fitted recessed, so that none of its metal parts protrude from the enclosure.

All equipment connected to K_2 must be powered from a separate supply, battery or adapter.

The operation of the monitor is simple to verify by plugging it into a mains socket and switching a nearby fluorescent tube on and off a few times. Set to the most sensitive range (50 V), the monitor is nearly always triggered if the mains outlet is on the same line as, and within 10 m from, the tube lighting. The number of 'hits' will be found to decrease as the sensitivity of the monitor is lowered, and the distance to the tube is increased. ■