Build this low cost project and . . .

Control appliances by telephone

Ring-a-ding! Ting-a-ling, ding-a-ling! This "Phone Controller" lets you dial your home number and switch a mains appliance on or off without paying for the phone call. You can use it to turn on outside lights, a spa or an electric blanket.

by JOHN CLARKE

How often have you been caught out at night and worried that your house was in total darkness? An unlit house is burglar bait, but it's not always convenient, or deemed necessary, to leave a light on when we go out.

Wouldn't it be nice if you could turn on a living-room light or the outside lights simply by dialling your home number? With this nifty little project, you can do just that.

Alternatively, you can use your Phone Controller to turn on any other appliance, so long as its rating does not exceed 2400W. There's simply no need to go home to an unlit house, a cold bed, or a non-bubbling spa.

So how does the Phone Controller work? The concept is really quite straightforward — the device is simply triggered by a preset number of phone rings and switches a relay to turn on the appliance. What's more, the phone call costs nothing since the device only counts the number of phone rings and does not answer the phone.

The accompanying photographs show the neat appearance of the prototype. The circuitry is all housed in a low profile plastic case which can sit under the telephone. At the rear of the unit is a mains outlet socket, while the front panel carries a power switch, a power on indicator LED, and an appliance indicator LED.

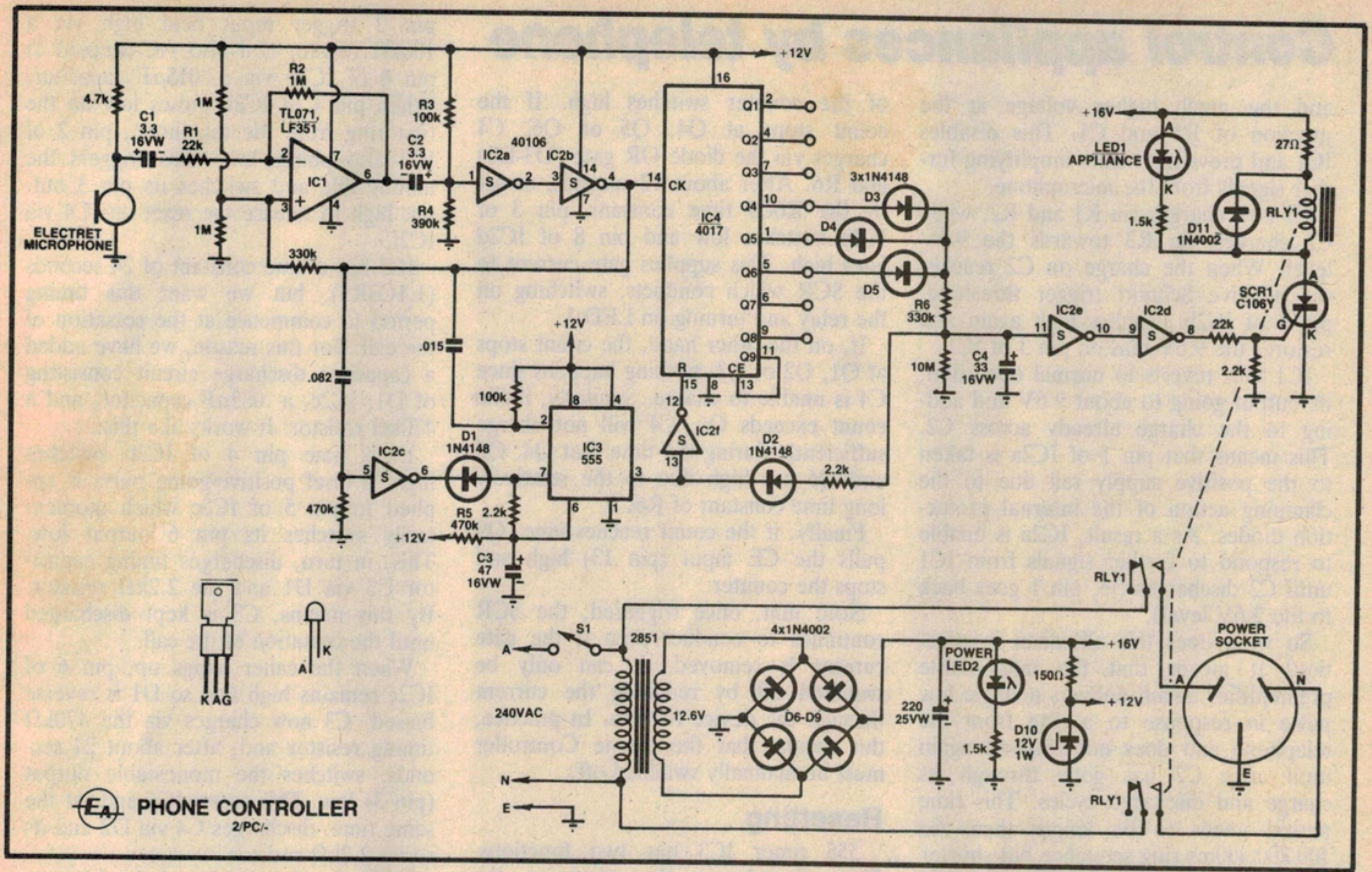
In operation, the appliance is plugged into the rear socket while the Phone Controller is plugged into the mains. An internal microphone listens to the telephone and passes the received ring signal onto a counter circuit. When the correct number of rings is detected, the appliance is switched on.

The Phone Controller is designed to sit underneath the telephone.

However, if the caller hangs up before the unit has counted the correct number of rings, or if the number of rings exceeds the preset number, the call will be ignored. This is to prevent the unit from being false-triggered by other callers.

Design features

It is here that we came to the first problem in designing such a unit. What number of rings should be selected to provide maximum security against false triggering? After much discussion, it was decided that five rings is the optimum number. It is sufficiently long to guard against a wrong number or spurious rings due to crossed lines etc, but



low enough to ensure that a legitimate caller will ring for longer.

As a final refinement, we have designed a plus and minus one ring error into the circuit to ensure reliable triggering. Thus the circuit will trigger on either four rings, five rings or six rings. If readers disagree with our optimum number, the circuit can easily be altered to trigger on another sequence of three numbers between one and eight.

In practice, the Phone Controller provides only low-level security against false triggering. This means that it should only be used with appliances where the repercussions of false triggering are not serious.

Note that the unit is designed to switch an appliance once only. Once the appliance has been switched on, it can only be switched off manually. Alternatively, the Phone Controller can be wired to switch the appliance off instead of on.

How it works

Fig.1 shows the Telecom specification for a telephone ring sequence. It consists of a 400ms long ring pulse, followed by a 200ms pause, another 400ms ring pulse, then a 2s pause, and so on indefinitely. For each 400ms ring pulse, the current is modulated by a 15-27.5Hz tone. It is this current that activates the bell striker within the telephone.

The internal circuitry of the Phone Controller processes the signal picked up by the microphone and produces a single pulse for each 400/200/400ms ring sequence. The resultant pulse train is then fed to a counter circuit. When the correct number of pulses is received, the output of the counter circuit remains high and activates the relay circuit.

Let's take a look at the circuit. It uses four ICs: a TL071 op amp, a 40106 hex Schmitt trigger, a 555 timer and a 4017 decade counter.

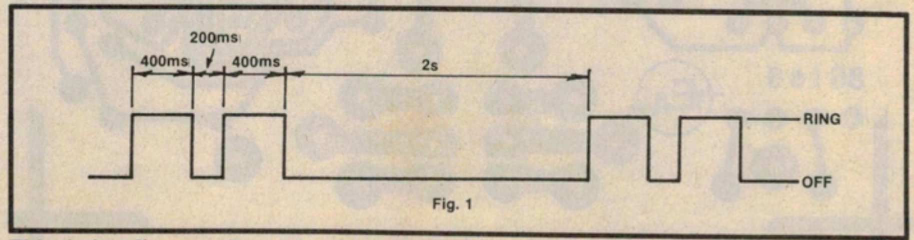
IC1, together with Schmitt triggers IC2a and IC2b, forms the microphone preamplifier. The signal picked up by the microphone is AC coupled to IC1 which is an inverting amplifier with a gain of about 45. Bias for the non-inverting input (pin 3) of IC1 is provided by two 1MΩ resistors and a 330kΩ feedback resistor from the output of IC2b.

The way in which the circuit works is rather devious. Here's what happens:

Initially, under no signal conditions, the output of IC2b is high and this biases pin 3 of IC1 to about 9.6V as set by the 330kΩ feedback resistor and the two 1MΩ resistors. Thus, pin 6 of IC1 will also be at 9.6V, as will the voltage on pin 1 of IC2a due to R3 and R4. Thus, C2 is initially discharged.

When a ring signal is subsequently received, the output of IC1 pulses low and this low signal is coupled, via C2, to pin 1 of IC2a. Pin 2 of IC2a thus switches high, while pin 4 of IC2b switches low and pulls pin 3 of IC1 to about 3V.

The output of IC1 now goes to ground due to the low voltage at pin 3



This timing diagram shows the standard telephone ring sequence.

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and the much higher voltage at the junction of R1 and C1. This disables IC1 and prevents it from amplifying further signals from the microphone.

C1 now charges via R1 and R2, while C2 charges via R3 towards the 9.6V level. When the charge on C2 reaches the positive Schmitt trigger threshold, pin 4 of IC2b switches high again and restores the 9.6V bias on pin 3 of IC1.

IC1 thus reverts to normal operation, its output going to about 9.6V and adding to the charge already across C2. This means that pin 1 of IC2a is taken to the positive supply rail due to the clamping action of the internal protection diodes. As a result, IC2a is unable to respond to further signals from IC1 until C2 discharges (ie, pin 1 goes back to the 9.6V level).

So what does this all mean in practice? It means that the microphone preamplifier circuit delivers a single low pulse in response to a ring from the telephone and does not respond again until after C2 has gone through its charge and discharge cycles. This time period needs to be longer than the 400/200/400ms ring sequence but shorter than two seconds so that the circuit can respond to the next ring sequence.

We have set this time to about 1.2 seconds.

The output of IC2b clocks decade counter IC4. As each positive going clock signal is received, the next output of the counter switches high. If the count stops at Q4, Q5 or Q6, C4 charges via the diode OR gate (D3-D5) and R6. After about 12 seconds, as set by the R6C4 time constant, pin 3 of IC2e switches low and pin 8 of IC2d goes high. This supplies gate current to the SCR which conducts, switching on the relay and turning on LED 1.

If, on the other hand, the count stops at Q1, Q2 or Q3, nothing happens since C4 is unable to charge. Similarly, if the count exceeds Q6, C4 will not charge sufficiently during the time that Q4, Q5 and Q6 are high due to the relatively long time constant of R6C4.

Finally, if the count reaches nine, Q9 pulls the CE input (pin 13) high and stops the counter.

Note that, once triggered, the SCR continues to conduct even if the gate current is removed. It can only be switched off by reducing the current through the device to zero. In practice, this means that the Phone Controller must be manually switched off.

Resetting

555 timer IC3 has two functions. First, it releases the reset on the counter when the first ring is detected so that it can begin counting. Second, it rearms the circuit some 24 seconds after the last phone call so that it cannot be disabled by other callers.

IC3 is wired as a monostable with its pin 2 trigger input held high via a 100kΩ resistor and also AC-coupled to pin 4 of IC2b via a .015μF capacitor. When pin 4 of IC2b pulses low on the first ring from the telephone, pin 2 of IC3 also pulses low. This triggers the monostable and switches its pin 3 output high to release the reset on IC4 via IC2f.

IC3 has a time constant of 24 seconds (1.1C3R5), but we want this timing period to commence at the cessation of the call. For this reason, we have added a capacitor discharge circuit consisting of D1, IC2c, a .082μF capacitor, and a 470kΩ resistor. It works like this:

Each time pin 4 of IC2b switches high, a brief positive-going pulse is applied to pin 5 of IC2c which momentarily switches its pin 6 output low. This, in turn, discharges timing capacitor C3 via D1 and the 2.2kΩ resistor. By this means, C3 is kept discharged until the cessation of the call.

When the caller hangs up, pin 6 of IC2c remains high and so D1 is reverse biased. C3 now charges via the 470kΩ timing resistor and, after about 24 seconds, switches the monostable output (pin 3) low. This resets IC4 and, at the same time, discharges C4 via D2 and its series 2.2kΩ resistor.

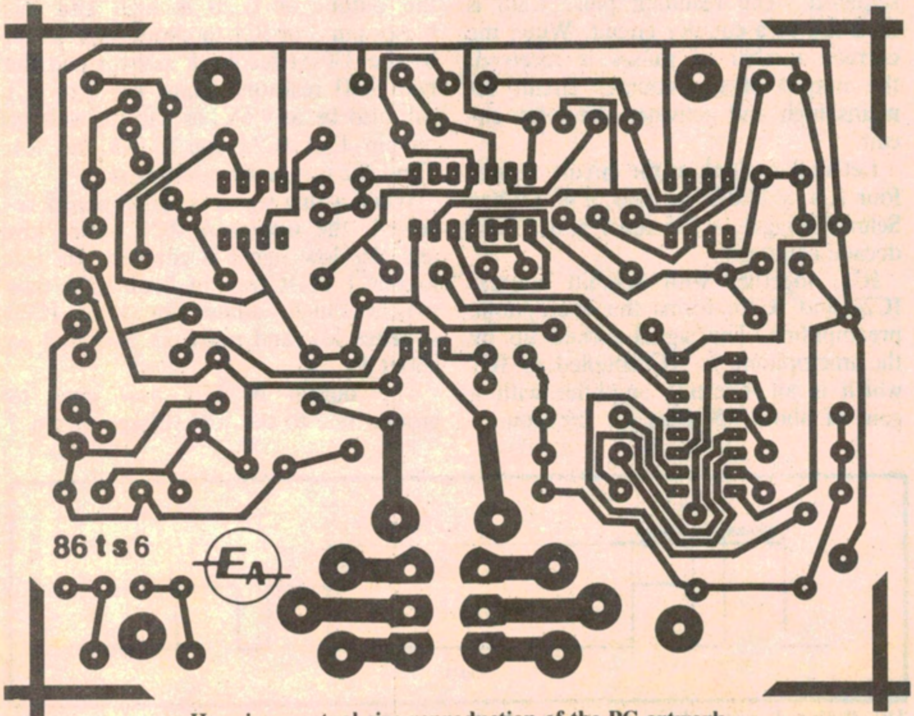
Power for the circuit is derived from a small mains transformer which drives a bridge rectifier circuit (D6-D9) and a 220μF filter capacitor. This produces an unregulated supply rail of about +16V which is used to power the SCR and relay circuitry.

Zener diode D10 is used to derive a +12V regulated rail to power the ICs. This is necessary to ensure that the maximum voltage rating of the ICs (16V) is not exceeded. LED 2 and its associated 1.5kΩ current limiting resistor provide power-on indication, while two-pole relay RLY1 switches the active and neutral lines to the mains socket.

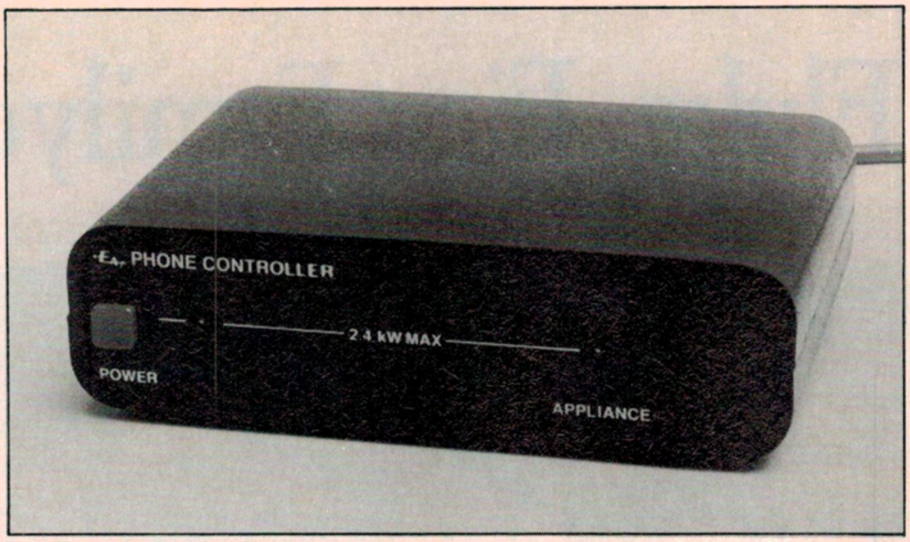
Construction

Most of the parts are accommodated on a small PCB coded 86ts6 and measuring 110 x 87mm. This is housed in a UB11 plastic case measuring 185 x 125 x 50 mm and distributed by Arista Electronics Pty Ltd. A Scotchcal adhesive label was used to give the completed project a professional appearance.

Begin assembly of the PCB by installing PC stakes at all external wiring points, except for the four mains connections adjacent to the relay. This done, the remaining parts can be installed on the PCB according to the wiring diagram. No special procedure need



Here is an actual size reproduction of the PC artwork.



The Phone Controller can switch appliances rated up to 2.4kW.

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be followed here although we suggest that the smaller parts be installed first.

Note carefully the orientation of the diodes, ICs, SCR and electrolytic capacitors when they are being installed. We installed D3, D4 and D5 at the Q4, Q5 and Q6 outputs of IC4, but readers can install these in other positions if they wish.

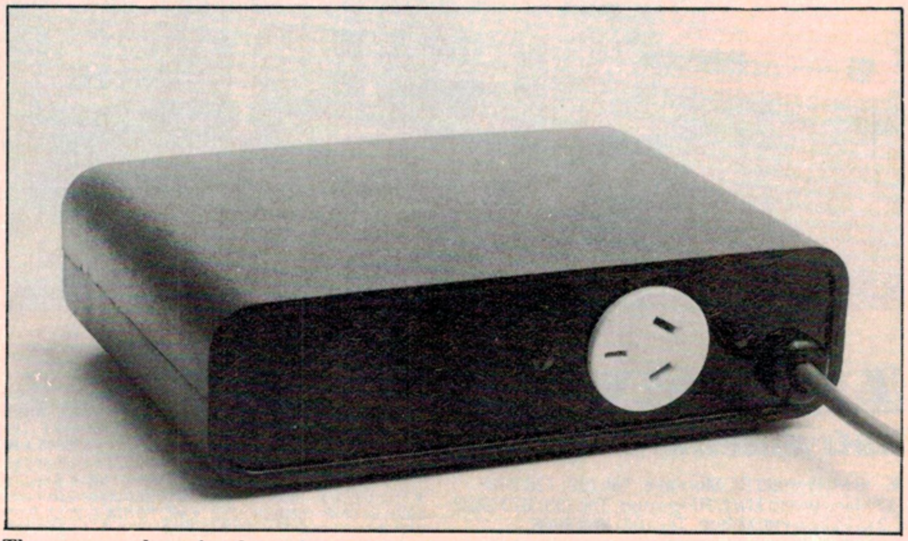
For example, you may decide that seven rings is the number that best suits your particular application. In this case, D3, D4 and D5 should be installed at the Q6, Q7 and Q8 outputs respectively of IC4. There are additional holes on the PCB to provide for this.

The electret microphone is supported on the PCB using two PC stakes. Note that it must be correctly oriented. The earth pin is the one that is connected to the case.

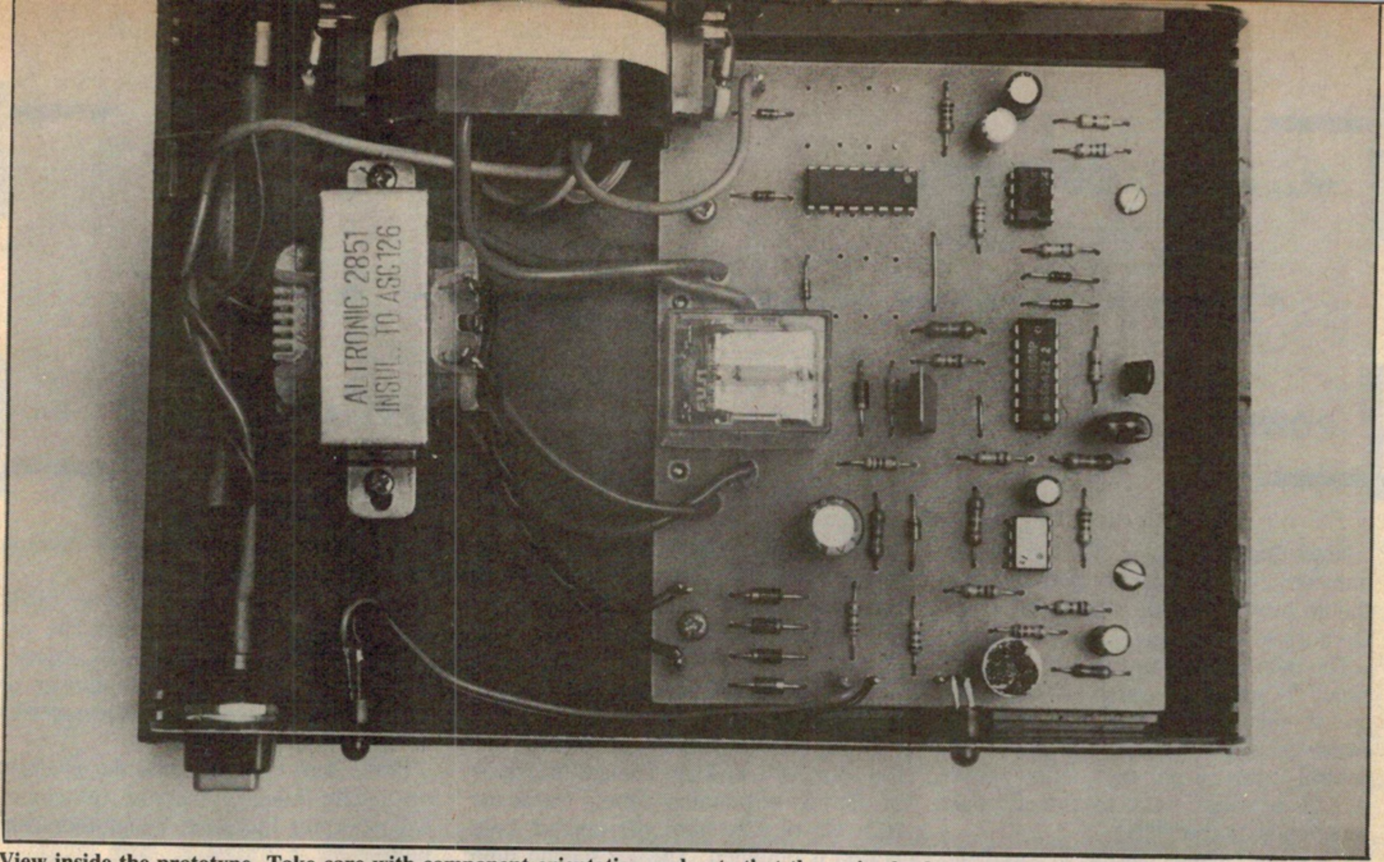
When the PCB has been completed, attention can be turned to the plastic case. Temporarily position the PCB in the case, then mark out and drill holes for the cord clamp grommet and mains outlet socket. The large hole for the mains outlet socket can be made by drilling a series of smaller holes around the inside perimeter of the marked circle, and then filing the cutout to a smooth shape.

The Scotchcal label can now be carefully affixed to the front panel and used as a drilling template. You will have to drill three holes in this panel — one each for the power and indicator LEDs, and one for the power switch.

This done, the various items of hardware can be installed in the case and



The rear panel carries the mains outlet socket and cord clamp grommet.



View inside the prototype. Take care with component orientation and note that the mains leads are soldered directly to the PCB.

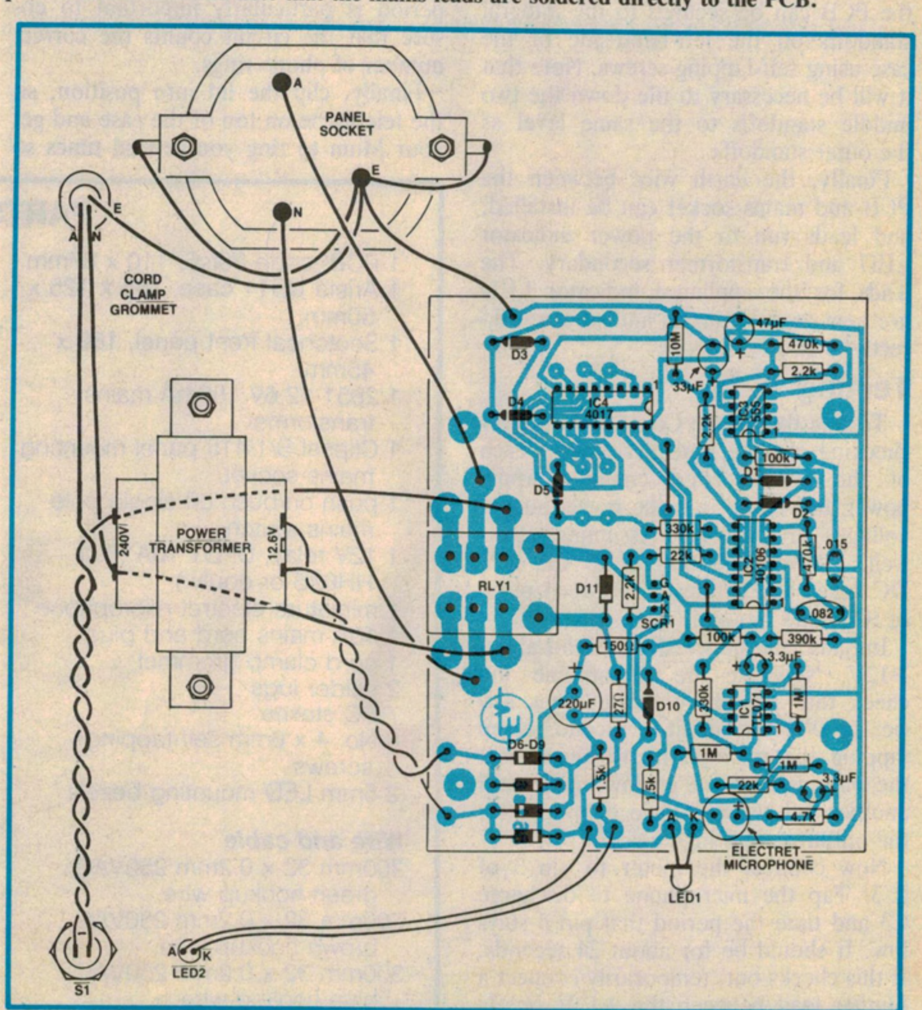
the two LEDs installed using LED mounting bezels. The transformer is mounted on two integral plastic standoffs and secured using self-tapping screws.

All that remains now is to complete the wiring. Note that mains-rated cable must be used for all wiring, except for the wiring to the power LED and to the transformer secondary.

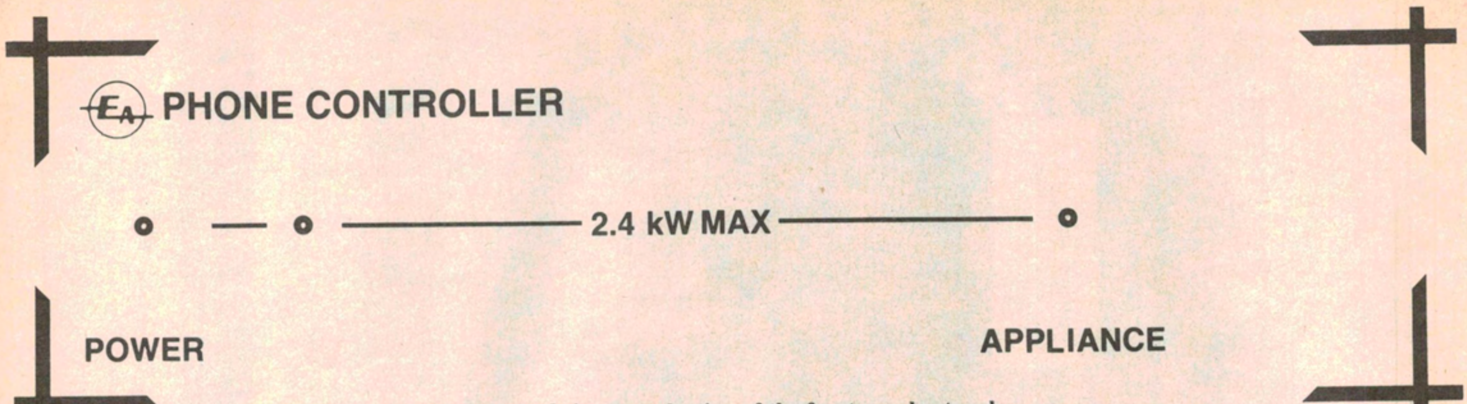
Strip back the outer insulation on the mains cord so that the individual wires are long enough to reach the mains switch from the rear panel, then secure the mains cord using the cord clamp grommet. Solder the active (brown) lead to the mains switch and the neutral (blue) lead to one side of the transformer primary. The earth lead (green/yellow) goes directly to the earth terminal on the mains outlet socket.

Leave the earth lead longer than necessary to ensure that, if the cord does slip out of the grommet, it is the active lead to the mains switch that comes adrift first. It is a good idea to insulate the terminals on the mains switch to prevent accidental contact with the mains.

We also suggest that you earth the mounting screws for the mains socket, as it is possible for these to come in contact with a loose mains wire. Install an earth lug under each of the mounting screws and run the leads from them to the earth terminal on the mains socket.



Above: parts layout and wiring diagram for the Phone Controller.



Above is an actual-size reproduction of the front panel artwork.

Note that the mains wires from the transformer and mains outlet socket should be soldered directly to the PCB. Do not use PC stakes.

The wiring diagram shows how the circuit is wired to switch an appliance on. If you want to use the circuit to switch an appliance off, the active and neutral leads from the outlet socket should be transferred to the adjacent spare pads on the PCB.

Once the mains wiring is complete, the PCB can be secured to the integral standoffs on the left-hand-side of the case using self-tapping screws. Note that it will be necessary to file down the two middle standoffs to the same level as the outer standoffs.

Finally, the earth wire between the PCB and mains socket can be installed, and leads run to the power indicator LED and transformer secondary. The leads for the appliance indicator LED are bent at right angles and soldered directly to two PC stakes.

Testing

Testing the Phone Controller involves checking out the time periods for each of the time related circuits. Apply power and check that the power supply voltages are correct. Assuming all is well, set your multimeter to the 20V DC range and connect it between pin 4 of IC2b and ground.

Initially, the meter should read about +12V. Now tap the microphone and check that the pin 4 output goes low (ie, to 0V) for about a second. Keep tapping the microphone to check that the output does not go low again until another 1.2 seconds have elapsed after the output swings high again.

Now connect the meter to pin 3 of IC3. Tap the microphone to discharge C3 and time the period that pin 3 stays low. It should be for about 24 seconds. If this checks out, temporarily connect a jumper lead between the +12V supply and the D3, D4 and D5 (cathode) side of R6. Measure the time it takes for the relay to pull in — it should be longer than nine seconds but less than the IC3 time period (preferably about 12 seconds).

Don't forget to remove the jumper lead after this step.

If any of the above time periods are too short or too long, change the value of the corresponding timing capacitor (C2, C3 or C4) until the correct time period is obtained. The 1.2 second time period is particularly important to ensure that the circuit counts the correct number of phone rings.

Finally, clip the lid into position, sit the telephone on top of the case and get your Mum to ring you several times so that you can check the circuit operation for various numbers of rings.

Alternatively, if you want to be really smart, dial 199 and hang up. The exchange will then ring you back automatically. You can control the number of rings simply by picking up the receiver at the appropriate time.

Make sure that you pick the receiver up quietly though, otherwise the circuit will interpret the noise as another ring pulse.

Finally, note that the circuit may not respond correctly unless the bell volume is turned up to somewhere near maximum. The bell volume is adjusted by means of a small knurled knob located on the underside of the receiver.

PARTS LIST

1 PCB, code 86ts6, 110 x 87mm
1 Arista UB11 case, 185 x 125 x 50mm
1 Scotchcal front panel, 180 x 45mm
1 2851 12.6V 150mA mains transformer
1 Clipsal S/1/415 panel mounting mains socket
1 push on/push off single pole mains switch
1 12V relay, DPDT 10A (Fuji HH62B or equiv.)
1 miniature electret microphone
1 10A mains cord and plug
1 cord clamp grommet
2 solder lugs
7 PC stakes
6 No. 4 x 6mm self-tapping screws
2 5mm LED mounting bezels

Wire and cable

300mm 32 x 0.2mm 250VAC green hookup wire
300mm 32 x 0.2mm 250VAC brown hookup wire
300mm 32 x 0.2mm 250VAC blue hookup wire
500mm 12 x 0.12mm hookup wire
50mm 0.5mm tinned copper wire

Semiconductors

1 TL071, LF351 JFET input op amp
1 555 timer
1 4017 decade counter
1 40106 hex Schmitt trigger
1 C106Y SCR
5 IN4002 1A diodes
5 IN4148, IN914 diodes
1 12V 1W zener diode
1 5mm red LED
1 5mm green LED

Capacitors

1 220μF 25VW PC electrolytic
1 47μF 16VW PC electrolytic
1 33μF 16VW PC electrolytic
2 3.3μF 16VW PC electrolytics
1 .082μF metallised polyester
1 .015μF metallised polyester

Resistors (1/4W, 5%)

1 x 10MΩ, 3 x 1MΩ, 2 x 470kΩ, 1 x 390kΩ, 2 x 330kΩ, 2 x 100kΩ, 2 x 22kΩ, 1 x 4.7kΩ, 3 x 2.2kΩ, 2 x 1.5kΩ, 1 x 150Ω, 1 x 27Ω.