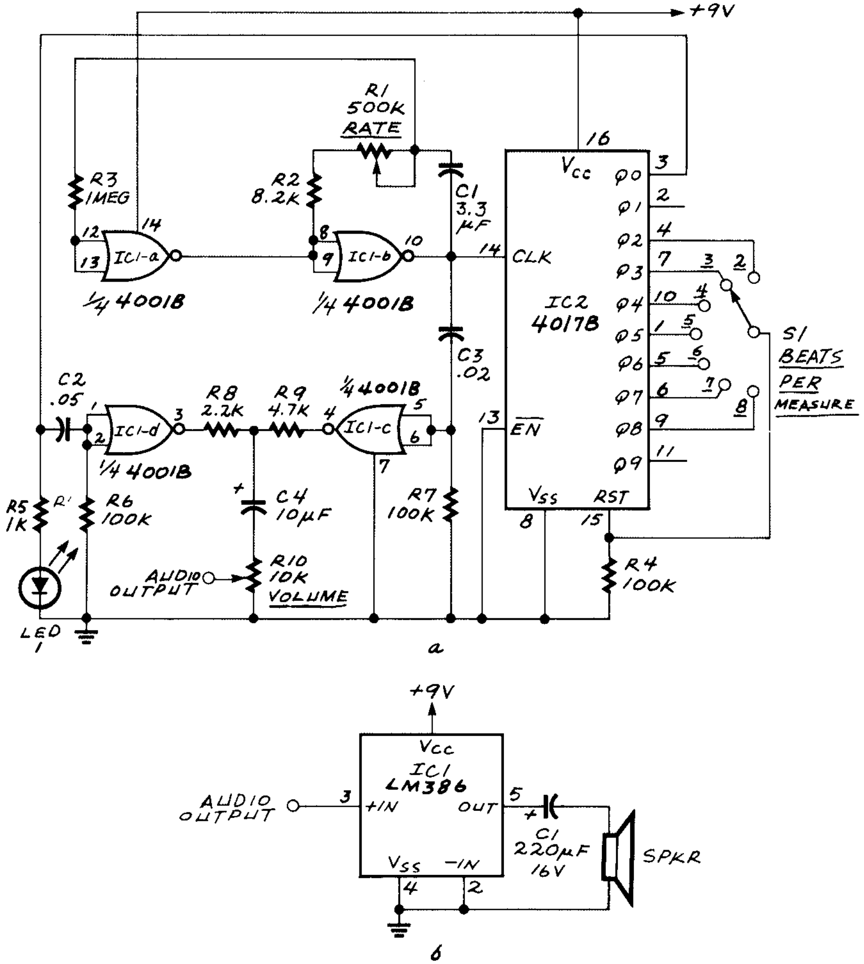


FIG. 1

ELECTRONIC METRONOMES HAVE LONG been popular with both electronics experimenters and musicians with a practical bent. All metronomes provide a steady stream of pulses, but few accent the first beat of the measure—the downbeat. The metronome presented here does, and it allows you to vary the counting rate from about 1 to 200 beats per minute. A rotary switch allows you to select an emphasized beat every other beat, every third beat, etc., all the way to once every nine beats.

As shown in Fig. 1-*a*, IC1-a and IC1-b form an astable multivibrator whose period of oscillation is approximately equal to $1/(2.2 \times C1\,(R1 + R2))$. The astable's signal is fed to IC1-c, which buffers the signal for further amplification. The astable's output is also fed to the CLOCK input of IC2, a 4017B (a 4017A is also suitable) decade counter. That IC's Q0 through Q9 outputs go high one at a time for each successive clock pulse received at pin 14. Switch S1 feeds one of those outputs to the 4017B's RESET input; whenever the selected output goes high, the 4017B restarts its counting cycle. That is what deter-

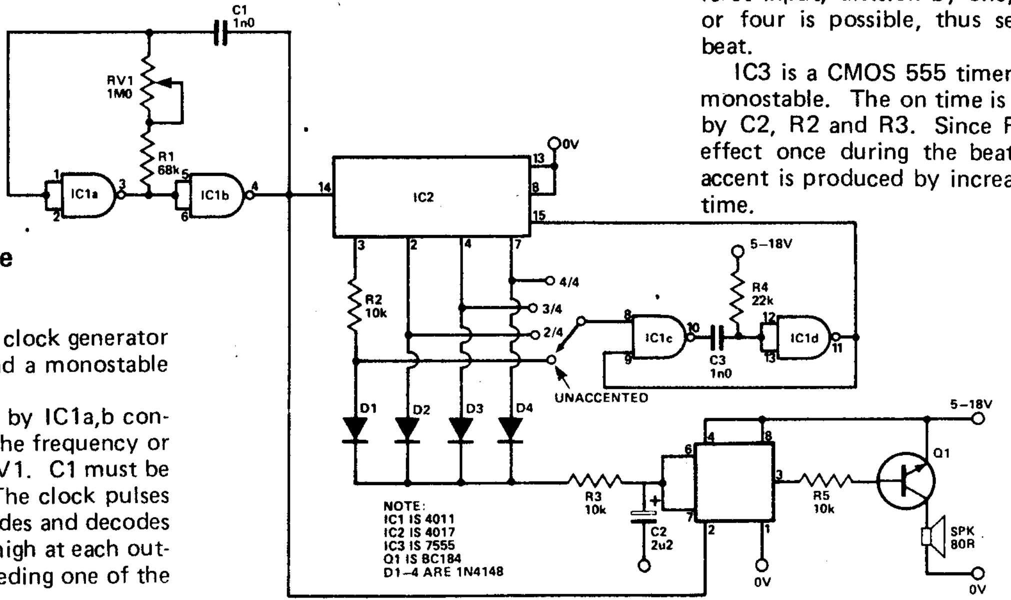
continued on page 111

Accenting Metronome
P. Hill

The circuit consists of a clock generator determining the beat and a monostable producing the accent.

The clock is formed by IC1a,b configured as an astable. The frequency or tempo is adjusted by RV1. C1 must be a non-polarised type. The clock pulses are fed to IC2. This divides and decodes the clock to produce a high at each output in succession. By feeding one of the outputs via monostable IC1c,d to the reset input, division by one, two, three or four is possible, thus selecting the beat.

IC3 is a CMOS 555 timer, forming a monostable. The on time is determined by C2, R2 and R3. Since R2 only has effect once during the beat cycle, the accent is produced by increasing the on time.



Reader's Circuit. In the majority of metronome circuits using simple R-C timing networks, the tempo (frequency) adjustment has most of its control "squeezed" near one end of the operating range. Seeking to minimize this problem, reader Richard K. Brush (1965 East 3375 South, Salt Lake City, UT 84106) decided to develop his own design for a metronome. His circuit (Fig. 2) features a nearly linear tempo control, loudspeaker output, and, interestingly, discrete devices rather than an IC.

Richard's major improvement is a shift from a voltage variable to a current-controlled charging source for the timing capacitor. Transistor *Q1A* provides temperature compensation for a voltage divider network consisting of *R2*, tempo control *R3* and *R4*. The tempo control's adjustment determines the base bias applied to *Q1B* which, in conjunction with limiting resistor *R1*, serves as a current source for timing capacitor *C1* in the UJT relaxation oscillator. The pulse oscillator's output, developed across base load *R6*, drives the power amplifier, *Q2*, which, in turn, delivers an output signal to a PM loudspeaker. The loudspeaker's voice coil is shunted by *D1*, to dissipate transient voltage peaks developed by sharp current pulses.

To keep costs low, inexpensive components are used. Dual transistor *Q1* is a Poly Paks type 14A 653 or type 2N1132, the UJT is type TIS43, and the output amplifier is a general-purpose npn power transistor, (Radio Shack No. 276-636 or similar). The damping diode, *D1*, is a general-purpose rectifier with a 1-A rating. Timing capacitor *C1* is a 15- or 20-volt electrolytic. An 8-ohm, 3" PM loudspeaker

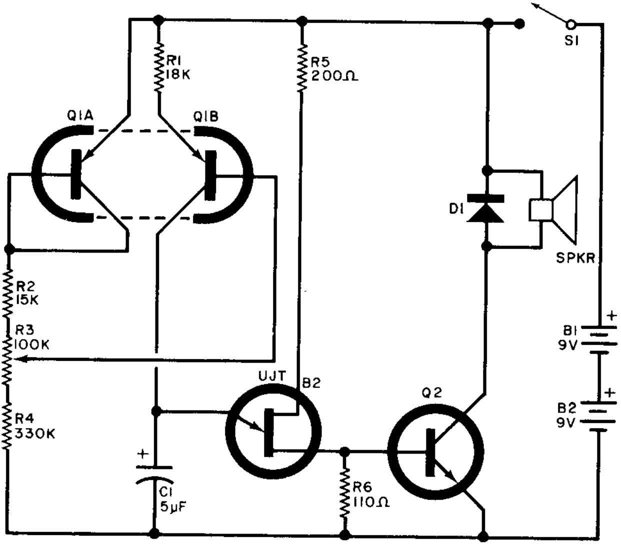
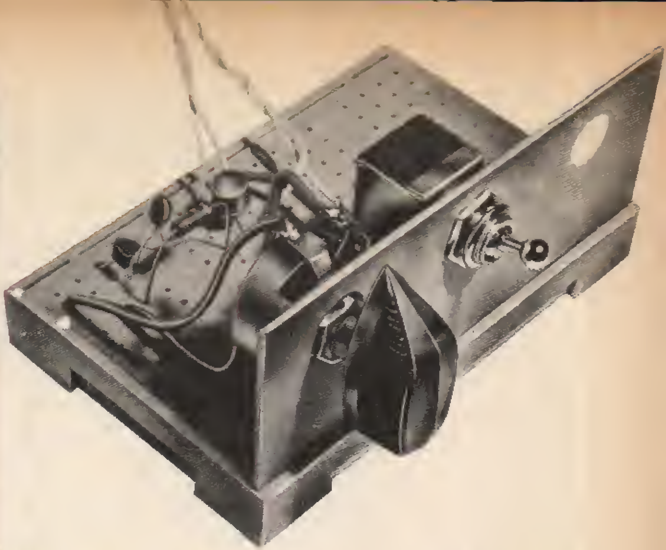


Fig. 2. Metronome circuit has a nearly linear tempo control and loudspeaker output.

was used in the original model, but larger units can be used if preferred. Finally, *B1* and *B2* are standard 9-volt transistor batteries.

Any construction technique can be used for duplicating the circuit. The completed unit, after check-out, can be calibrated using another metronome or a stopwatch.

Richard writes that his original model has a range of 30 to 220 beats per minute, but this may vary with component tolerances. The range can be shifted by using different values for *R1* and *R2*. Current limiting resistor *R1's* value determines the overall tempo, while *R2's* value establishes the minimum-to-maximum ratio. The use of a UJT type other than the one specified may require different values for *R5* and *R6*.



To study a musical instrument, one of the most important requirements is strict attention to playing speed. To assist in the correct interpretation of the music's tempo the composer conveniently heads his composition with a rough guide to the rate at which it should be played like *Andante* or *Allegro*, this usually being followed by the number of crotchets, quavers, etc. that should be played per minute.

Whilst the accomplished musician has little difficulty in interpreting these tempo marks, the beginner does need some sort of aid to assist in establishing a sense of time.

More than a hundred years ago Maelzel provided such an aid in his invention of the mechanical metronome which produced loud ticks with the movement of a weighted pendulum. With the simple electronic metronome to be described, we can reproduce these ticks just as effectively without the labour of winding up springs.

RELAXATION OSCILLATOR

To simulate the sound of its mechanical counterpart the circuit of Fig. 1 was designed to produce asymmetric pulses of short width and rapid rise and fall times. The pulse generated across the loudspeaker LS1 is shown in this diagram, and it ensures a very rapid cone movement.

The frequency range extends from 40 to 220 beats per minute, which is adequate.

As this little device is very precise in its counting, it can also be used as an audible "darkroom" timer when set to 60 beats/minute.

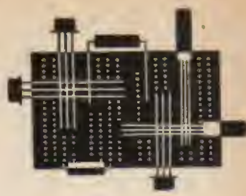
The circuit itself is a simple relaxation oscillator where two complementary *npn* and *pnp* transistors are made to switch on and off at a rate determined by the resistance chain VR1, R1 and capacitor C1. With S1 closed, C1 charges until it reaches about 650mV when TR1 is switched on and immediately discharges the capacitor.

The current pulse produced by TR1 in turn switches on TR2 with the result that almost the whole of the supply voltage is made to appear across the loudspeaker.

The actual discharge time of the capacitor depends on the base-emitter impedance of TR1, the loudspeaker impedance and the output impedance of TR2 which collectively account for the exponential hump on the output pulse waveform.

With the completion of the pulse the capacitor again charges to the conduction potential of TR1, when the pulse cycle starts again.

METRONOME



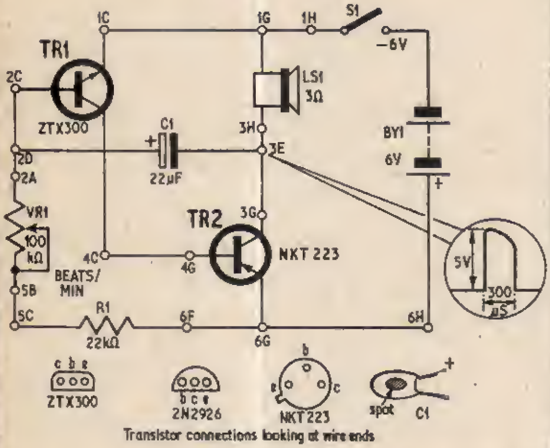


Fig. 1. Circuit diagram of the metronome showing the T-Dec hole connections, transistor wire identification and output waveform

LOW LEAKAGE

In the application of this unit timing precision is important. The simple factor most likely to give trouble in this aspect is leakage current. The choice of a silicon transistor for TR1 and a tantalum electrolytic capacitor for C1 virtually eliminates the problem.

In the choice of speaker it will be found that sound output is a function of cone diameter. In practice, a 5in speaker proved very satisfactory.

CONSTRUCTION

Construction of the unit merely involves plugging the components into the T-Dec as shown in the photograph. For the holes employed refer to Fig. 1, which shows the hole numbers for each junction.

If it is intended to make a permanent unit of this, the wiring configuration will readily translate to any of the board constructional methods outlined in the introductory article.

If such construction is undertaken the potentiometer setting must be calibrated in terms of the number of beats produced per minute. Using a wrist watch with seconds sweep or preferably, a stop watch, the potentiometer should be advanced at 20 beat intervals. These positions can be recorded on a piece of white card. A pointer knob attached to the potentiometer shaft will simplify this operation.

COMPONENTS . . .

Resistors
R1 22kΩ 10% ½ watt carbon

Potentiometers
VR1 100kΩ linear carbon

Capacitor
C1 22μF tantalum elect. 16V

Transistors
TR1 ZTX300 (Ferranti) or 2N2926 orange spot
TR2 NKT223 (Newmarket) or GET102 (Mullard)

Switch
S1 on/off toggle switch

Loudspeaker
LS1 3Ω 5in permanent magnet moving coil unit

Battery
BY1 6V type 996

Miscellaneous
T-Dec.
Single strand connecting wire
Battery connectors or clips

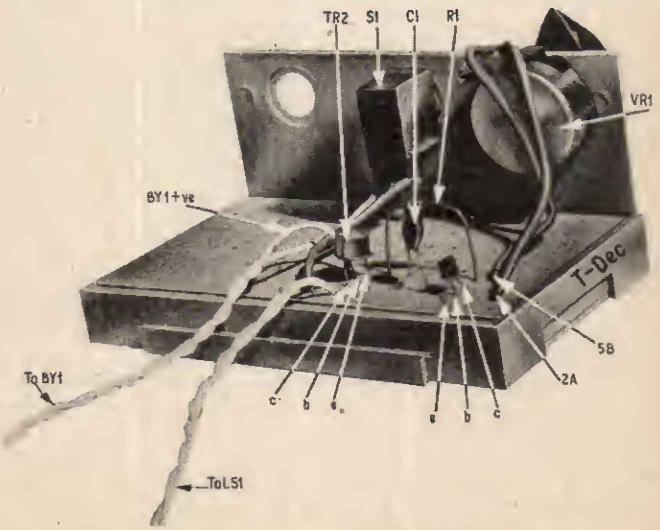
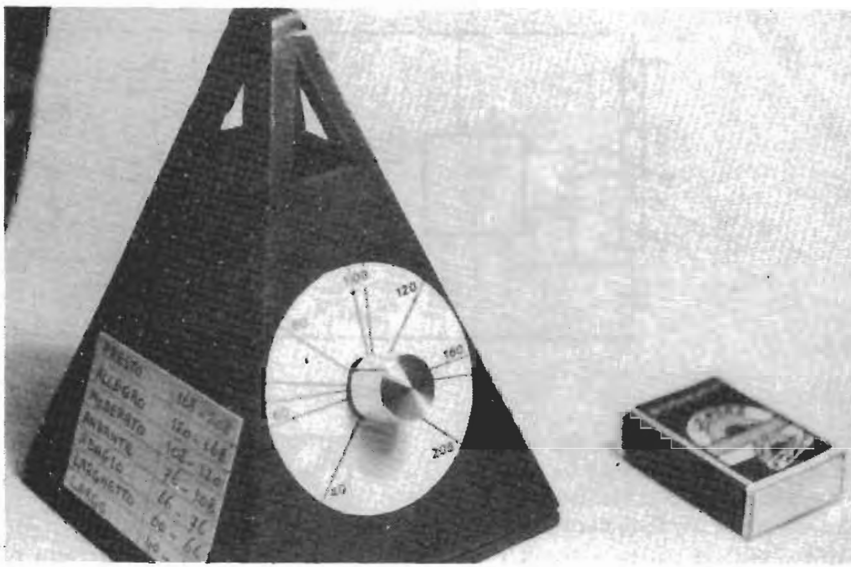


Fig. 2. The layout of components on T-Dec. Make sure the battery is correctly connected

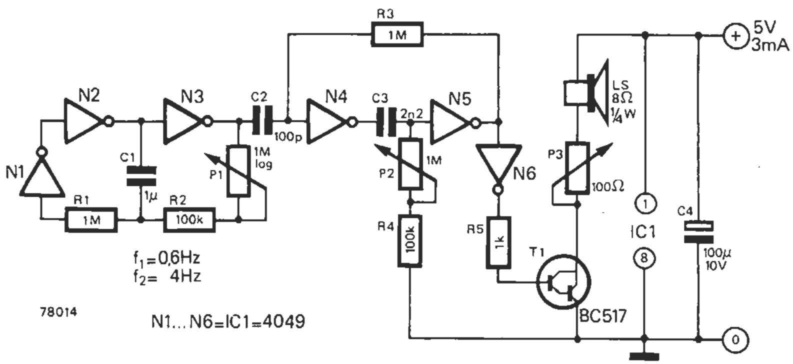
15 metronome

B. v.d. Klugt

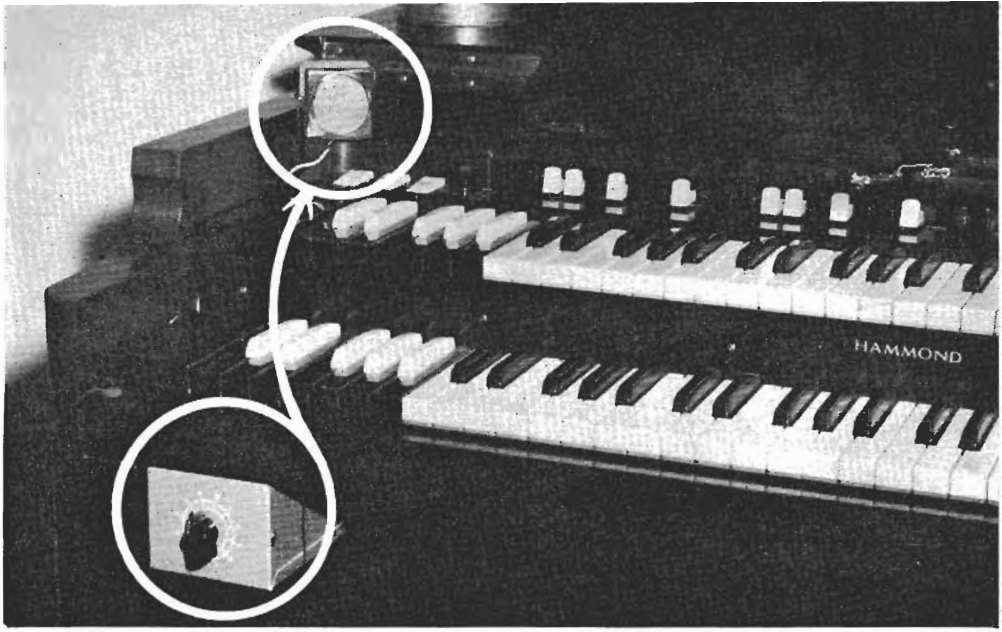


Those of our readers who have experienced the pleasures of piano lessons during their childhood, will doubtless be all too familiar with the sound of a metronome. This is a clockwork instrument with an inverted pendulum, which can be set to beat a specific number of times per minute, the loud ticking thereby indicating the correct speed at which the passage of music should be played. Although mechanical metronomes are still used almost universally, it is, of course, also possible to achieve the desired effect electronically.

The circuit for an electronic metronome described here is distinguished, not by any revolutionary new features, but by its extreme simplicity and excellent stability. N1 to N3 form an astable multivibrator. By means of P1, the frequency of its output signal can be varied between 0.6 and 4 Hz, whilst the pulse width can be adjusted be means of P2. The latter control modifies the sound of the beat between a short 'dry' tick and a longer, fuller tone. The volume control is provided by P3, which varies the peak current through the loudspeaker between 0.5 A and 50 mA. At low resistance values of P3, the resultant large current places fairly heavy demands upon the transistor, and hence a Darlington pair was chosen. Thanks to the low duty cycle, the average current drawn by the circuit is extremely small, so that an ordinary 4.5 V battery will suffice for the power supply.



The accompanying photo shows how the characteristic shape of the metronome can still be conserved in the electronic model.

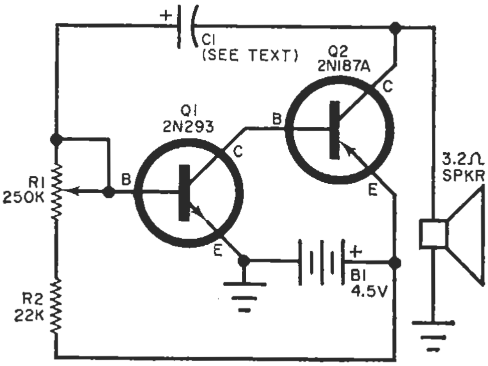


On the Beat Electronically

THE FAMILIAR spring-wound, pyramid-shaped metronomes used by musicians since the time of Beethoven are giving way to the clicking of electronic timers. The transistorized electronic metronome (seen above, with remote speaker) is a compact, battery-operated unit that can be adjusted for any musical tempo. Clicks produced at the miniature speaker are of sufficient amplitude to override the sounds of most musical instruments.

You can construct the metronome to suit your own particular needs. In the photo above, the speaker is mounted in a small but attractive case, sitting on top of the organ, while the remainder of the unit is housed in an aluminum chassis box under the keyboard. Pianists may want the electronic metronome mounted all in one case, with rubber feet, to rest on top of the piano. How *you* do it is up to you.

Audio amplifier with added feedback circuit (C1) produces "motor-boating" clicks for timing beats.



Follow the schematic diagram carefully as you wire the circuit. Resistor *R2* is a 22,000-ohm, ½-watt unit, and *C1* is a 15-µf. electrolytic rated at 5 to 10 w.v.d.c. Be sure *C1*'s negative (unmarked) lead connects to the collector of transistor *Q2*. Then connect the 4.5-volt battery, *B1*, making certain that the polarity is correct.

Now check the number of clicks with potentiometer *R1* fully clockwise, and then fully counterclockwise. The metronome should cover a range of 40 to 210 beats per minute or better. If it cannot go down to 40 beats, increase the value of *C1*. If it's necessary to increase the upper limit, lower the value of *C1*. But vary the capacitor's value by no more than 10% at a time until the desired limit is reached.

The author used a Burgess Type N3 battery with snap-in terminals to power his unit. When the battery is snapped out of the circuit, the metronome stops clicking, and the removed battery serves as a "key" to prevent unauthorized use of the device.

—*John J. Borzner*

BY FRED BLECHMAN
AND DAVID McDONALD

A LED PENDULUM METRONOME

An electronic replacement for the old mechanical music timer

The mechanical metronome, reputedly invented by Maezel in the 19th century, has been a familiar sight around musicians and music students for many years. It uses a wind-up clock mechanism to swing a weighted arm, generating a series of clicks as the escapement gears make contact. The clicking rate is conventionally adjustable from 40 to 210 beats per minute by positioning the weight on the calibrated oscillating arm to change the moment of inertia and the rate of the swing.

Redoubtable though it may be, Maezel's brainchild suffers from defects common to all mechanical devices: wear, drift of calibration, and the need for fairly frequent maintenance. In addition, it must be wound often. A battery-operated, solid-state electronic design, such as the LED Pendulum Metronome described here, circumvents or alleviates the problems of the mechanical metronome. It is stable in calibration and reliable.

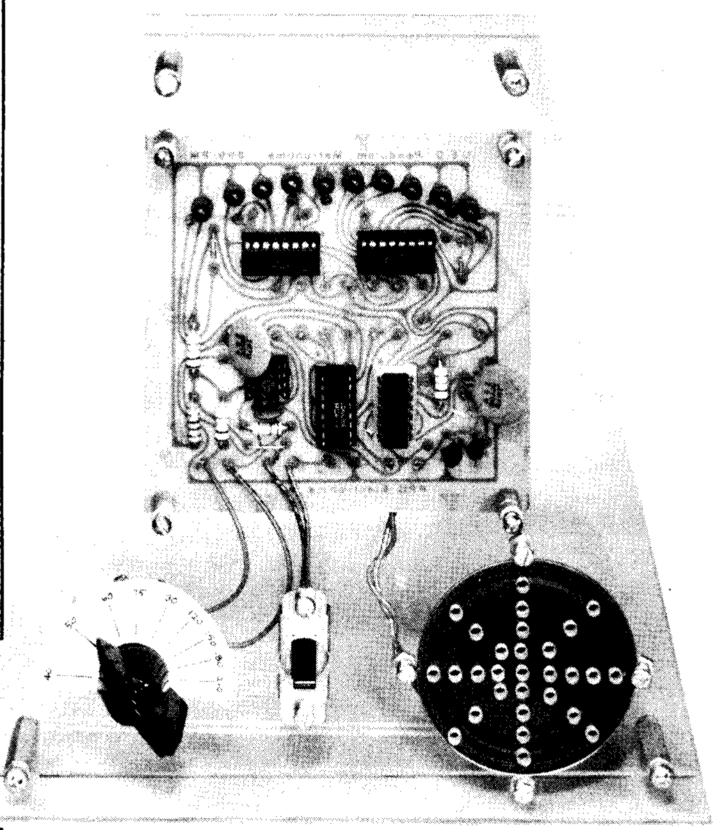
Partly for nostalgic reasons, the pendulum movement of the mechanical metronome is simulated in the project as a flashing sequence of LEDs arranged in an arc. (A click from a loudspeaker occurs as the LED at either end of the string fires.) However, the LEDs offer the user the option of "reading" the metronome signal visually in circumstances where a click might be inaudible or objectionable to the user.

Circuit Operation. The "beats" are generated by *IC1*, which is used as an oscillator (Fig. 1). Resistors *R1*, *R3*, and capacitor *C1* limit the frequency of operation that can be set by means of potentiometer *R2*. Capacitor *C2* decouples the *IC1* modulation input. Each cycle of operation of *IC1* results in a positive-going pulse at pin 3, which is fed to the clock input of up-down counter *IC4*. This counter can be set to count from 0 to 9 (10 counts) or 0 to 15 (16 counts), depending on the status of pin 9. With pin 9 positive (as shown), *IC4* counts from 0 to 15. Counting up or down is controlled by pin 10; positive for up-counting, ground for down-counting. The A, B, C, and D outputs of *IC4* (pins 6, 11, 14, and 2) go positive in a 4-bit binary sequence with the D output (pin 2) low during counts 0 to 7 and high during counts 8 to 15.

Both *IC2* and *IC3* are identical 1-of-8 switches. Depending on the 3-bit binary input, one of eight outputs is connected to pin 3 through a low resistance (typically 120 ohms). This is called the "on" condition for this pin. The A, B, and C inputs to *IC2* and *IC3* (pins 11, 10, and 9) are addressed by the output pins (6, 11 and 14, respectively) of *IC4*. However, *IC2* or *IC3* must be enabled by a low on pin 6. For counts 0 to 7, pin 2 of *IC4* is low, enabling *IC2*. Notice, however, that pin 6 of *IC3* is high because of *IC5A*, one section of a quad 2-input NAND gate, wired as an inverter. This disables *IC3* while *IC2* is enabled.

As *IC4* counts from 0 to 7, the outputs of *IC2* are turned "on" in sequence. In this case, on is *not* ground, but is an internal low resistance to pin 3, which is grounded. This low resistance to ground allows the LED connected to an on pin to glow.

Only five LEDs are connected to the eight outputs, with *LED1* connected to three outputs, *LED2* to two outputs, and *LED3*, *LED4*, and *LED5* to one output each. This is done to simulate the swinging motion of a pendu-



lum, which is fastest near the center but slows down near each end of its swing as it finally stops and reverses. By using multiple counts for the LEDs farthest from the center, the apparent motion of the pendulum seems to slow down, stop, and reverse at each end of its swing. This same technique is used for the five LEDs connected to *IC3*.

As *IC4* counts from 0 to 7, only *IC2* is enabled, with *IC3* cut off. When *IC4* reaches the count of 8, the D output at pin 2 goes high. This turns off *IC2*, but, via the inversion by *IC5A*, *IC3* is enabled, lighting LEDs 6 to 10 in sequence. Therefore, the first eight counts of *IC4* are used to command the *IC2* outputs, and the next eight counts command *IC3* outputs.

Up to this point, *IC4* was counting up since its pin 10 was high. This is controlled by the output of a flip-flop formed by NAND gates *IC5B* and *IC5C*. When power is first turned on by closing switch *S1*, pin 9 of *IC5B* is pulled high through *R6*, and pin 5 of *IC5C* is pulled low by pin 13 of *IC2*. Pin 4 of *IC5C* is therefore high since it has a low on at least one input. Pin 4 is connected to *IC4* pin 10, so *IC4* counts up. The flip-flop holds this high on pin 4 of *IC5C*, even though the first count changes pin 5 of *IC5C* to a high. On count number 15 (actually the sixteenth count, if you start at 1 instead of zero), pin 4 of *IC3* is switched on (low resistance to ground). This pin is directly connected to pin 9 of *IC5B*, pulling it low, so output pin 10 of *IC5B* goes high. This provides a high input to pin 6 of *IC5C*. Since pin 5 is already high, pin 4 of *IC5C* goes low to switch *IC4* to the down-counting mode. Even though *IC5B* pin 9 goes high on the next count, the flip-flop logic keeps pin 4 of *IC5* low.

When *IC4* gets down to the zero count, pin 13 is turned on, and pin 5 of *IC5C* is pulled low, making pin 4 of *IC5C* high, and thus putting *IC4* in the up-counting mode. The top count of *IC4* then causes the flip-flop to again change the output at pin 4 of *IC5C*. This flip-flop action keeps occurring at each end of the pendulum, causing it to "swing" back and forth. Capacitors *C4* and *C5* prevent noise from accidentally changing the up/down mode of *IC4*.

The clicking sound occurs at each end of the pendulum swing (as counts 0 and 15 are reached) by changing the state of *IC5D*. Pins 12 and 13 of *IC5D* are normally high, so pin 11 is in a low

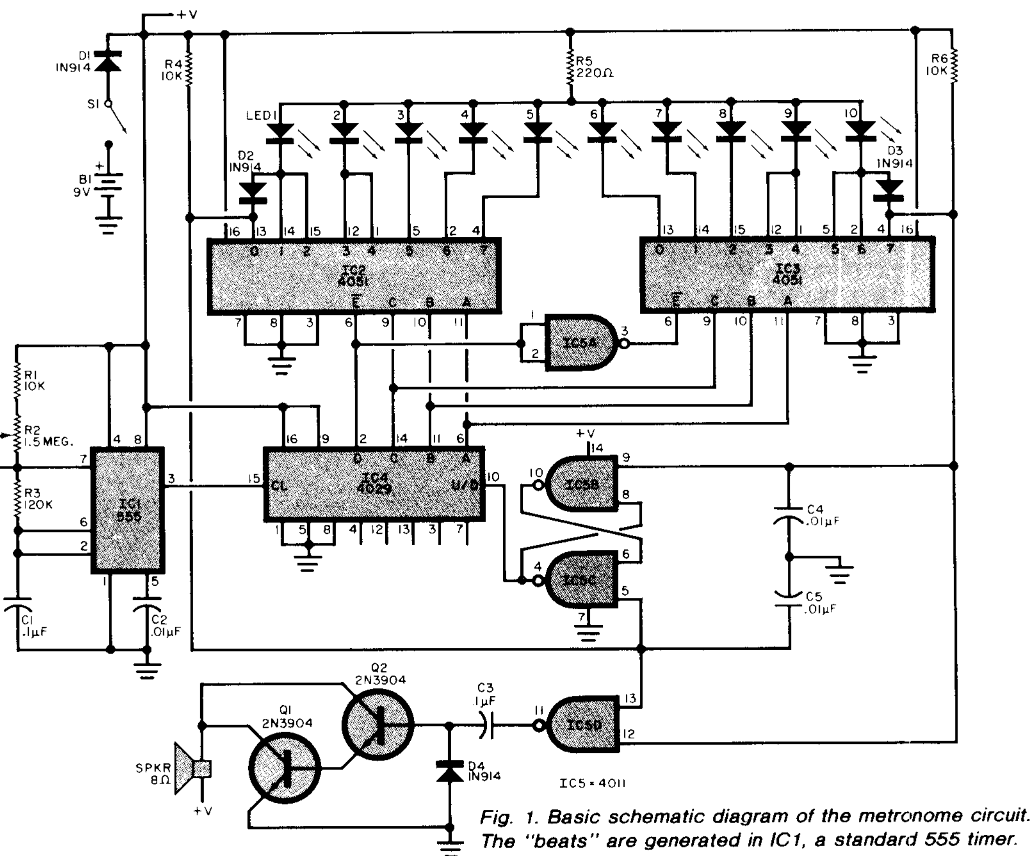


Fig. 1. Basic schematic diagram of the metronome circuit. The "beats" are generated in IC1, a standard 555 timer.

PARTS LIST

B1—6-to-9-volt battery (see text)
C1,C3—0.1-μF disc capacitor
C2,C4,C5—0.01-μF disc capacitor
D1 through D4—1N914 diode
IC1—555 timer
IC2,IC3—4051 1-of-8 switch
IC4—4029 up down counter
IC5—4011 quad 2-input NAND
LED1 through LED10—Jumbo red LED
Q1,Q2—2N3904 or similar transistor
R1,R4,R6—10-kΩ, ¼-W, 10% resistor
R2—1.5-MΩ, liner-taper potentiometer
R3—120-kΩ, ¼-W, 10% resistor
R5—220-Ω, ¼-W, 10% resistor
S1—Spst switch
SPKR—Miniature 8-Ω speaker
Misc.—IC sockets (optional), battery holder, knob, suitable enclosure, mounting hardware, etc.

Note: The following is available from PPG Electronics Co., Inc., Dept. B, 14663 Lanark St., Van Nuys, CA 91402 (213-988-3525): complete kit of parts including pc board (PM-K) at $14.95. Also available separately: plastic "cabinet" (PM-C) at $9.95; etched and drilled pc board (PM-B) at $5.95. Add $2 shipping and handling. California residents, add 6% sales tax. No foreign orders.

state. When *IC2* pin 13 or *IC3* pin 4 is pulled low, on counts 0 or 15 respectively, pin 12 or 13 of *IC5D* is made low, and pin 11 of *IC5D*, following NAND logic, goes high. This positive voltage swing charges *C3*, causing a small positive pulse to forward-bias transistors *Q1* and *Q2*, which are arranged in a Darlington circuit. The small current pulse through the series-connected base-emitter circuits of *Q1* and *Q2* enables a larger current flow from the power source, through the speaker and the collector-emitter circuit of *Q1*. This is heard as a click. When pin 13 of *IC2* or pin 4 of *IC3* goes high on the next count, a high is put back on pin 12 or 13 of *IC5D*. Pin 11 goes low again, and capacitor *C3* is discharged through diode *D4*. Since transistor *Q2* is now reverse-biased, there is no sound from the speaker until the pendulum "swings" to the other end.

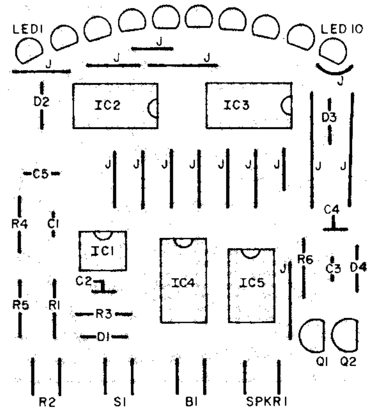
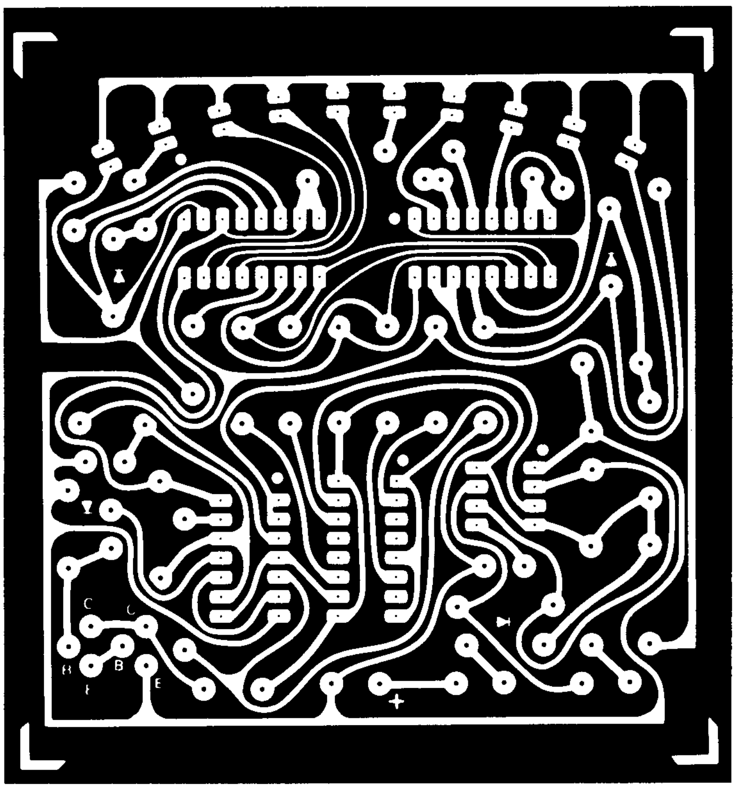


Fig. 2. An actual-size foil pattern for a printed-circuit board is shown below. Above is the component layout diagram. Install jumpers first.



Diodes *D2* and *D3* block the low voltage from pins 14 and 15 of *IC2* and pins 5 and 2 of *IC3* so the count is not prematurely reversed. Diode *D1* prevents damage to the circuit from reversed power leads, or from inserting the battery backwards.

Construction. The LED Pendulum Metronome circuit can be built on a perforated board with point-to-point wiring. However, there are 120 terminations for the ICs, resistors, capacitors, diodes, and transistors—and this doesn't count the external speaker, potentiometer, switch, and battery wiring. Thus, it is more convenient to use the printed-circuit pattern and parts layout shown in Fig. 2.

If you use the pc board, assembly is straightforward. A small 25-watt soldering iron and resin-core solder should be used. First, install the 15 jumpers shown in Fig. 2, cutting wires to the appropriate length and trimming about 1/4" of insulation from each end. Insert through the top of the board and solder on the foil side. Next, install and solder the resistors and diodes, making certain the bands (cathodes) on the diodes are properly oriented. Next, solder in the five sockets, but do *not* install the ICs yet. Now, solder in the three capacitors. The LEDs must be installed in the proper orientation. The cathode (bar of arrow symbol) is identified by a flat-spot or notch at the base of the LED, and the cathodes of all LEDs face the main portion of the circuit board. Next, solder in the transistors, with the flat side facing as shown, so the E, B, and C leads are properly placed. Solder two leads each for the speaker, switch, battery, and potentiometer, and your circuit board wiring is completed.

Your final packaging will dictate the placement of the external parts and the lengths of the leads. Double-sided tape can be used to mount the speaker to the foil side of the board. Potentiometer *R2* should be located below the circuit board to allow room for a calibrated scale and knob on whatever front panel you use. The switch and battery leads can be located wherever convenient.

A unique, modern package is provided by using two sheets of Plexiglas with spacers and screws used to mount the circuit board sandwich-fashion, as shown in the photo.

Since all the ICs have a broad voltage operating range (roughly 3 to 15 volts), you have a choice of what battery configuration to use. At 9 volts, the circuit draws an average of 30 mA, so it's practical to use a standard 9-volt transistor radio battery. Used 4 hours daily, a standard 9-volt zinc-carbon battery (such as Burgess 2V6) should last about 5 hours; an alkaline 9-volt cell should run at least 20 hours. For long, hard use, it would be less expensive to use four "AA" pen cells, "C" or "D" cells wired in series to provide 6 volts initially. Although the LEDs will not be quite as bright and the clicking not as loud, the average current drain is only about 20 mA. Four regular zinc-carbon pen cells should run the metronome for almost 50 hours, used 4 hours a day. Using zinc-carbon "C" cells under the same conditions you can expect 125 hours of use. Alkaline batteries will provide from 4 to 10 times as much useful life. Actually, the circuit will operate with as little as 3 volts, and only uses an average of 4 mA at that voltage—but it's not very loud or bright, so not as effective!

Testing & Calibration. It's a good idea to test and calibrate the unit before final installation in whatever cabinet you're using. Install the ICs carefully in their sockets, making sure they are oriented properly and that no pins are bent out or under. Since all the ICs except *IC1* are CMOS devices, take precautions to avoid static electricity when handling them. Solder the speaker, switch, potentiometer, and battery connector (if used) to the leads from the circuit board and don't forget the jumper across two of the potentiometer terminals.

Connect the battery power and turn on switch *S1*. If nothing happens, make sure that *D1* is not connected "backwards" and that battery polarity is correct. If any individual LED does not light, it may be soldered to the board backwards. If only one LED lights, the 555 (*IC1*) may not be operating. Check for the presence of positive voltage on pins 4 and 8, and see that pin 1 is grounded. Also make sure the values for resistors *R1* and *R3* and capacitor *C1* are correct. As always, solder connections should be checked. If the LEDs swing properly, but you hear no sound, check transistor installation and diode *D4* polarity. If you encounter problems beyond that, an ohmmeter, logic probe, and the circuit description should allow you to pinpoint the problem.

Calibration ideally requires a stopwatch, but a sweep-second watch or seconds-counting digital watch will do. You'll also need patience. The major calibration points are 60, 120, and 180 beats per minute (bpm), since these are 1, 2, and 3 beats per second. You can tell pretty closely in a 15-second timing period what the minute-rate will be for a particular pointer setting by just multiplying the number of beats by four. By trial and error, mark the pointer scale at these points. Next find the 90, 150, and 210 bpm points. Once you've found these points, space the other points equally between the calibrated points and you'll be close enough for all but precision use. If the clicking sound is too loud, add a resistor (up to 100 ohms) in series with either speaker lead. (A 100-ohm potentiometer or variable resistor can be used as a volume control if desired.)

The LED Pendulum Metronome is not intended to be used in precision-timing applications, but is a modern version of an established musical teaching aid. ◇

Electronic Metronome Has Neon-Lamp Time Indicator

The complete metronome is built in an aircraft radio jack box. The original switch is used.

By O. A. COPPENS

ARTICLES have appeared in magazines in the past few years on the construction of several types of metronomes, the majority ranging from complicated tube assemblies to special relays and unwieldy capacitors. Following the old pattern of mechanical metronomes, the audible beat seems to be almost a requisite for any device described.

An audible beat interferes with the music, so a metronome of this type is generally used for rehearsal or timing practice only. On the other hand, an inconspicuous *visual* metronome provides a check on timing, may be used at any time, and in no way interferes with the music.

A simple, inexpensive, and fairly accurate visual metronome may be constructed from a selenium-rectifier power supply and a neon-bulb relaxation oscillator. Inconspicuous but usable flashes covering a wide frequency range may be obtained from small standard radio components.

A glance at the schematic (Fig. 1) shows the selenium-rectifier power supply to be conventional. R1 is the rectifier protective resistor; R2 and R3 with the filter capacitors form the filter and voltage-divider network. Approximately 140 volts is applied to the oscillator circuit. The power consumption is small, so heating effects are negligible.

Operation of the neon-bulb relaxation oscillator is as follows: When the device is plugged into a 117-volt supply socket and the switch moved from OFF position, current from the d.c. power supply flows through R4 and R5 to charge gradually any capacitor combination switched across the neon bulb. When the capacitor voltage builds up to a certain definite value (90 volts, approximately), the neon bulb ionizes and conducts. This action discharges the capacitance, and the neon bulb stops conducting. The capacitance then slowly recharges through R4 and R5, and the cycle repeats.

The frequency of the neon flashes is approximately proportional to the supply voltage and inversely proportional to the values of the R-C combinations. Rough frequency control is obtained by switching the various capacitor combinations across the neon bulb. This permits four rough steps of overlapping frequencies with only four small capacitors. The fine control of each step is provided by the high-resistance potentiometer R5 and R4. The high-resistance values of R4 and R5 are also a factor in permitting the use of small capacitors.

A continuous frequency range of approximately 30 to 350 flashes per minute may be obtained. Some alteration in the fixed resistor values may help to obtain

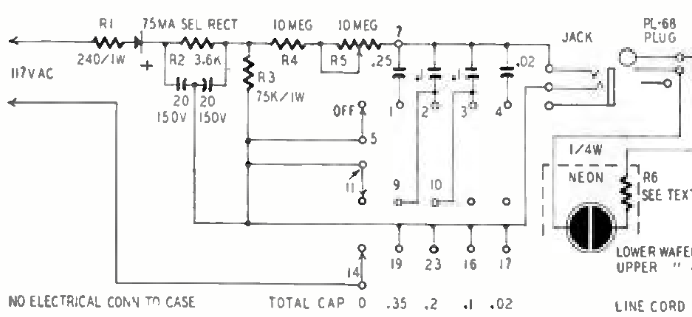


Fig.1

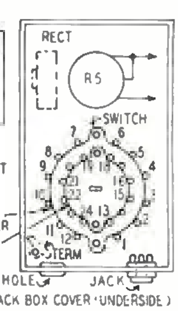


Fig.2

Fig. 1—The circuit diagram. Fig. 2—The switch contact numbers refer to those in the diagram.

correct overlapping of ranges. Due to the high resistances used, well-insulated components and good-quality capacitors are of prime importance for stability and proper operation.

Changes in supply voltage will have some effect on frequency. However, this effect is so small that it is not important in a metronome.

Construction

The metronome was constructed around a war surplus BC-366 jack box, available for a few cents. The box provides an excellent case (2¼ × 3¼ ×4½ inches) together with the required switch, 3-circuit jack, and the control knobs.

Photographs show the original jack box, the complete metronome, and the internal assembly of the metronome. All components except the neon extension are mounted and wired on the box cover for ease of construction and inspection. The box is completely isolated from the electrical circuit to avoid possible shock.

Remove the jack box cover and strip all the wiring. Also remove the banana jack and plug assemblies from the cover and base, as they will not be needed. Replace the original potentiometer with

After wiring the switch, the fiber banana-plug strip is placed over contacts to insulate them.

To get into jack box, remove two top screws.

a 10-megohm unit, cutting the shaft to fit the original knob. The single-circuit PHONE jack may next be removed and a rubber grommet inserted in the hole to accommodate the line cord.

Construct a small metal angle bracket for rectifier support, and bolt the rectifier assembly near one corner of the box cover as shown in Fig. 2 and the inside photo. A two-lug terminal strip is also bolted to the cover near the line-cord opening for cord connection and support. A few small holes may be drilled in the cover and base for ventilation.

Remove the rotary switch from the box cover and pry out the spring retention which makes the fifth (CALL) position momentary. This will provide for five switch positions. The switch may then be remounted, using the original knob. The banana-plug insulating strip (not the plug assembly) is remounted in position above the switch, using the original assembly screws, to provide a barrier between switch and capacitors.

A ¼-watt neon bulb is connected to an insulated two-wire extension cord terminating in a three-circuit PL-68 plug. If no plug is available, the neon extension may be connected directly to the metronome circuit by removing the three-circuit MIC jack and inserting a rubber grommet, similar to the line-cord hole. The value of the neon resistor R6 will depend upon the type of neon bulb used. It could be located in the box instead of the extension. A tubular fiber shield with hole, as shown in the photographs, slipped over the neon bulb, will direct and intensify the flashes.

Connect the rectifier power supply, all resistors, and the neon jack according to the schematic. To simplify connections to the switch terminals, an arbitrary numbering system corresponding to numbers shown on the schematic is shown in Fig. 2.

With the power supply on and the neon extension plugged in, temporarily connect various capacitor combinations until the desired ranges and overlaps are obtained by operation of the switch and R5. After the capacitors have been selected, mount and wire them permanently. Ample space is available for 400-volt capacitors. During construction, one 600-volt unit was used merely because it happened to be of correct value, sufficient mounting space being available near the side.

When the metronome is assembled and tested, a paper dial plate may be glued on the cover indicating the OFF position and each frequency range.

MATERIALS FOR METRONOME

Resistors: 1—3,600 ohms, ½ watt; 1—240, 1—75,000 ohms, 1—10 megohms, 1 watt; 1—10 megohm potentiometer.

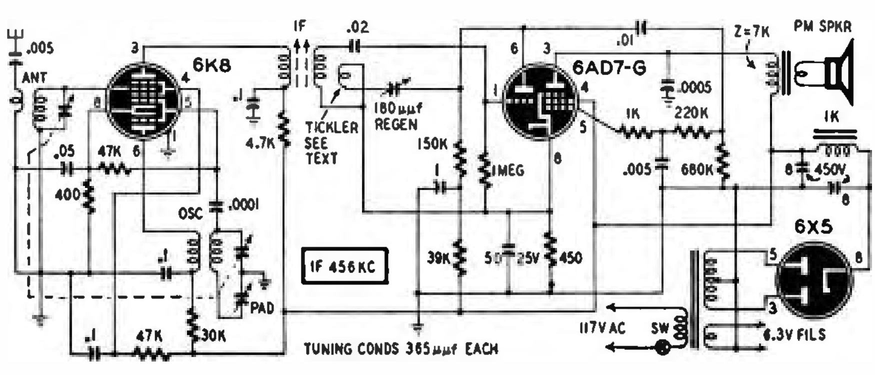
Capacitors: 2—20 µf, 150 volts, electrolytic; 1—.02, 2—0.1, 1—0.25 µf, 400 volts, paper.

Miscellaneous: 1—75-ma selenium rectifier; 1—3-circuit microphone plug (PL-68); 1—¼-watt neon lamp; 1—BC-366 jack box; necessary hardware.

REGENERATIVE SUPERHETERODYNE RECEIVER

The 6K8 in this receiver converts the incoming broadcast-band signal to the 456-kc i.f. The regenerative triode section of the 6AD7 is the second detector, and the pentode section the audio amplifier.

The tickler coil is added to an ordinary slug-tuned i.f. transformer. Close-wind 15 turns of No. 20 d.c.c. wire 3/16 inch below the transformer secondary. The antenna and oscillator coils are standard commercial broadcast units available at any parts store—*Manolis Samárakis.*



6 A simple metronome

Introduction

A metronome is a device used by musicians to indicate the tempo of a piece of music. Until electronics came on the scene, this 'beating of time' was achieved in much the same way as a clock keeps time, i.e. with a pendulum device, the clicking of the escapement indicating the beats of the music.

Those of you who have already built the Morse Key and Buzzer from the designs in this book, will recognise the circuit of this metronome – it is exactly the same as was used to produce the note of the buzzer. This circuit is shown in **Figure 1**.

The circuit

Three components determine the speed at which the circuit oscillates – the speaker (LS), the resistors (VR1 + R1) and the capacitor (C1). VR1 is a variable resistor, so that the speed at which the oscillator operates can be varied. Compared with the component values of the Morse Buzzer (which operated at around 800 Hz), these components now give an oscillation frequency of around 1.25 Hz, which is far too low to be heard as a note. What we *do* hear, however, is a series of clicks, as the voltage across the speaker changes quickly from 0 to 9 V and back again.

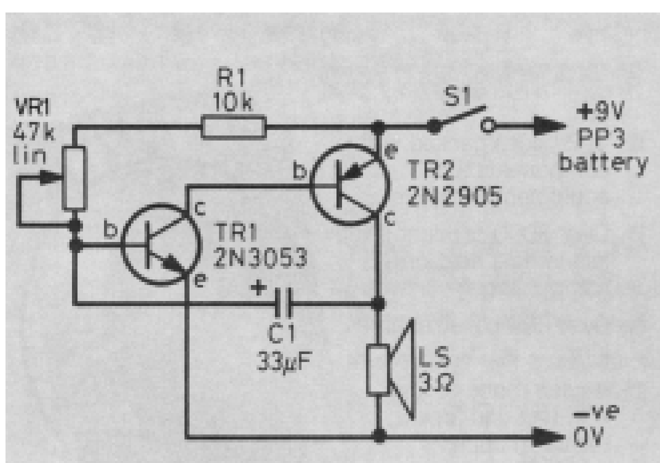


Figure 1 The metronome circuit is rather like the Morse oscillator

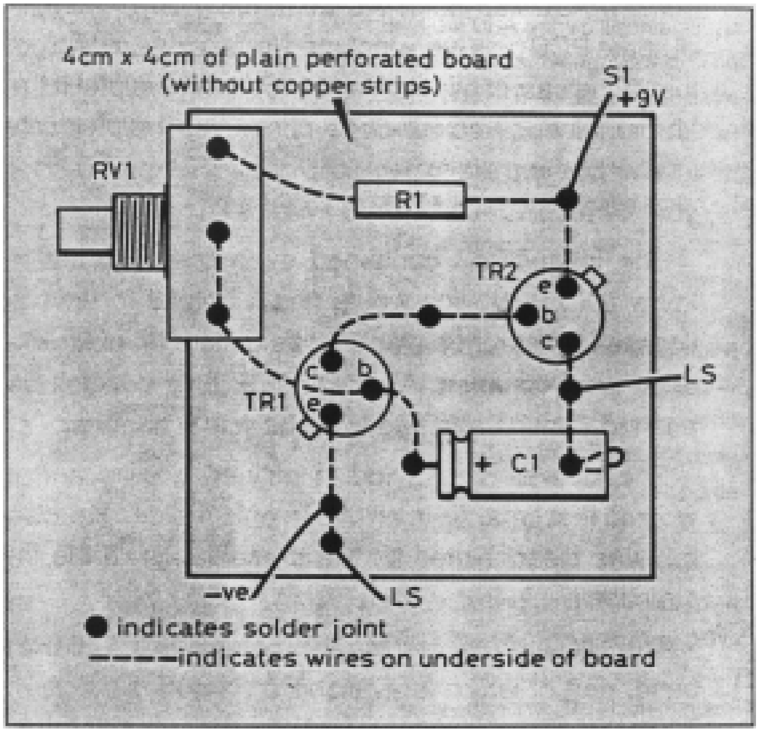


Figure 2 The component wires are pushed through holes in the circuit board and joined together underneath

Variation of speed could be achieved by varying resistance or capacitance. However, as you may already know, variable capacitors have values in the picofarad range, not the tens of microfarads used here, so it is very simple to employ a variable resistor (potentiometer) to control the oscillator. You could use a multi-way switch to switch in one of several capacitors, as well as having the variable resistor, but this was found to be an unnecessary complication. This design operates between about 100 clicks per minute and 200 clicks per minute.

Making the prototype

A single piece of plain matrix board (no copper strips) measuring about 40 × 40 mm is sufficient to hold all the components except the potentiometer and switch (see later). The case can be plastic or aluminium, and one measuring 65 × 100 × 50 mm is about right. Make sure there are holes in the case beside the speaker cone to let the sound out, and larger holes for the potentiometer and switch. If a potentiometer is used with a combined ON/OFF switch, then the extra hole for the switch is not necessary! It is advisable to construct the circuit *before* putting it in the box, so that it can be tested to ensure that everything is working. If it is, then you can exercise your ingenuity in mounting the speaker, battery and board inside the box. A final test can be made before starting the calibration process.

Calibration

There is no 'easy' way to do this. The frequencies involved are too low to be measured with the average frequency counter, so you will need to resort to using a stopwatch and counting the number of clicks per minute.

Parts list

Resistors: 0.25 watt, 5% tolerance

R1	10 kilohms (kΩ)	
VR1	47 kilohms (kΩ) linear potentiometer	

Capacitor

C1	33 microfarads (μF) electrolytic	

Transistors

TR1	2N3053	npn
TR2	2N2905	pnp

Additional items

S1	SPST	ON/OFF switch
LS	3 ohms (Ω)	loudspeaker
	Knob with pointer for VR1	
	PP3 battery and connector	
	Aluminium case, 65 × 100 × 50 mm	
	Matrix board (plain), 40 × 40 mm	

Simple metronome uses two transistors

Basic Electronics

Over the past 12 months or so we have had quite a few requests for a simple metronome circuit. This new circuit has low current drain and drives a loudspeaker as well as a LED indicator and even at maximum volume from the loudspeaker the current drain is still less than one milliamp.

by PAUL DE NOSKOWSKI

Some five years have elapsed since we last published a design for an electronic metronome – in the July, 1976 issue, to be precise. That unit featured an accented beat, wherein certain clicks in the sequence are accentuated to simulate the down-beat at the beginning of each musical bar. However, this increases the complexity of the circuit, and is reflected in both increased expenditure for parts and increased battery consumption.

In our new simplified design, we have been able to keep the battery drain down to less than 1mA!

Most readers will at some time or other have heard or seen a conventional mechanical metronome, which is built into a pyramidal shaped case containing a clockwork escapement mechanism. A spindle emerging from the base end supports an upright pendulum, carrying a brass weight, which can be locked into the desired position. When set in motion, the pendulum oscillates from side to side producing an audible click.

Both the visual movement and audible click serve as a guide to musical tempo, or beat. The tempo range covered by a mechanical metronome is usually between about 40 and 170 beats per minute, and is varied by sliding the brass weight up and down the pendulum, with the rate being displayed on a calibrated scale on the body (behind the pendulum).

The two main requirements in a metronome are that the rate at which the clicks occur should be constant and repeatable, and that the clicks should be "non-musical" in character.

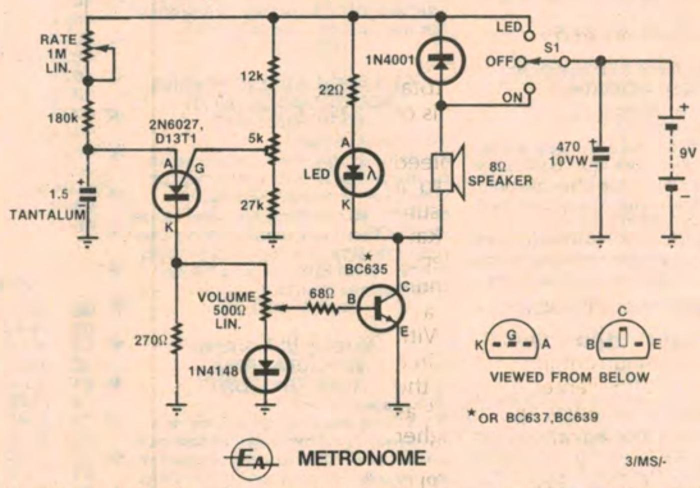
In this latest design we have used a programmable unijunction transistor (PUT) as the basic oscillator, since it can perform almost as well as a 555 timer in the areas of temperature and voltage stability, yet consumes far less supply current (which is about 5mA in the case of the 555). We also considered using a 7555 (the "CMOS" version of the ubiquitous 555), which only draws some 100μA, but rejected it on the grounds of increased cost and somewhat limited availability.

A PUT is really not a unijunction transistor at all but is actually a special low current type of silicon controlled rectifier (SCR) which has an anode gate instead of a cathode gate. A conventional SCR with cathode gate requires that its gate be raised about 0.5 volts above its cathode in order for it to conduct.

An anode gate SCR is different in that it requires that its anode be raised above its anode gate by about 0.5 volts (or thereabouts) for it to conduct. This enables it to be used in relaxation oscillator circuits and give improved performance compared to a unijunction transistor.

In our circuit the PUT has its gate connected to a preset voltage provided by an adjustable divider consisting of a 5kΩ trimpot and two resistors. When power is applied to the circuit, the 1.5μF capacitor begins to charge via the 180kΩ

Our new metronome features a level control and has an output of between 30 and 160 beats per minute.



The circuit uses a 2N6027 programmable unijunction transistor as the oscillator.

resistor and 1MΩ "rate" control potentiometer. When the voltage across the 1.5μF capacitor rises just a little above the preset gate voltage, the PUT suddenly breaks into conduction and dumps the capacitor charge across the 270Ω resistor connected to its cathode. When the capacitor is fully discharged (in about one millisecond) the PUT switches off and the cycle can repeat itself. Thus the circuit is a classic example of a relaxation oscillator, with the voltage waveform being a sawtooth (slowly rising ramp and rapid decay) with an amplitude controlled by the preset voltage. At the same time, there is a string of positive pulses appearing across the 270Ω cathode load resistor.

By varying the setting of the rate control, we can vary the frequency of the sawtooth waveform across the capacitor and the rate of the pulses across the cathode resistor. At the same time, the 5kΩ trimpot allows us to accurately set the sawtooth frequency for a particular setting of the rate control. The accompanying oscilloscope photograph shows the voltage waveforms at the anode and cathode of the PUT.

Virtually no current is drawn by the PUT during the charging segment of the oscillator cycle; and when the PUT conducts, the stored charge in the tantalum capacitor provides the anode/cathode current flow. Thus the current drawn from the supply is the sum of charging current and the "bleed" current flowing through the gate biassing network. Charging current will be dependent on the setting of the Rate control, varying between approximately 6μA and 35μA – typically about 20μA. As bleed curent is some 200μA, the total current drawn by the PUT oscillator is of the order of 220μA.

It should be noted that the bleed current has been deliberately set to a relatively high value in order to ensure satisfactory PUT oscillation with the Rate control set to the highest frequency (minimum resistance), when minimum performance PUT devices are encountered in this circuit. With insufficient bleed current (ie, high source impedance being presented to gate) the oscillator will commence "misfiring" as the Rate control is advanced to higher repetition rates.

The output pulses from the PUT cathode are used to drive a single transistor which acts as a rudimentary amplifier stage to drive a LED and a small loudspeaker. The volume of this amplifier stage is controlled by feeding the pulse waveform into the transistor base via a 500Ω volume control potentiometer and 68Ω limiting resistor.

A 1N4148 diode is connected in series with the volume control. If this diode was omitted, there would be a noticeable "dead spot" at minimum settings of the control due to the fact that the transistor does not begin to conduct until the voltage applied to its base exceeds around 0.6V. The diode compensates for this in the following way:

When the output pulse voltage appears at the cathode of the PUT, it is divided so that about 0.6V appears across the 1N4148 diode and the remainder of the pulse voltage appears across the 500Ω volume pot. This means that when the volume control is set fully anticlockwise, the transistor will barely conduct when each pulse appears but the loudness of the clicks from the loudspeaker will increase progressively as the volume control is advanced. And this system works well no matter how "sick" the battery becomes and how weak the PUT output pulses become.

As a matter of fact the PUT will continue to oscillate at battery voltages down to about four and a half volts although at this level, the available loudness from the loudspeaker is quite restricted.

We arranged the on/off switch to select either the LED alone or both LED and loudspeaker. When the on/off switch feeds the power directly through to the loudspeaker load for the transistor, the rest of the circuit is fed via the 1N4001 diode, so that the LED flashes each time a click sounds from the loudspeaker. When the LED is selected, the diode blocks current to the loudspeaker which is silenced. The on/off switch is a single-pole, double throw type with a "centre-off" position.

Readers may wonder why the 470μF capacitor is connected directly across the battery instead of on the circuit side of the on/off switch. The capacitor is intended to supply the brief pulses of current to the loudspeaker which the battery becomes increasingly incapable of doing as it ages. In other words, the capacitor ensures a low supply impedance. But the reason the capacitor is connected directly across the battery is an interesting sidelight to this project.

In our original prototype the capacitor was wired between the junction of the diode and loudspeaker, and the 0V side of the circuit. However, we found that when the LED only function was selected by the on/off switch, the loudspeaker continued to produce clicks. At first we could not understand how this could happen since the loudspeaker was supposedly isolated from the supply. But in actual fact, it wasn't!

What was actually happening was that in the comparatively long "off" time

PARTS LIST

1 "zippy" box, 130 x 68 x 41mm
1 Scotchcal panel label
1 printed circuit board 81mi11, measuring 57 x 35mm
1 "small" 8Ω loudspeaker (57mm diameter)
1 9 volt battery,
1 battery retaining clip
1 clip lead set for battery
1 SPDT (centre "off") toggle switch
2 knobs

SEMICONDUCTORS

1 small red LED (3mm diameter)
1 1N4001 diode
1 1N4148 doide
1 2N6027 (D13T1) programmable unijunction transistor
1 BC635 (or BC637, BC639) small signal transistor

CAPACITORS

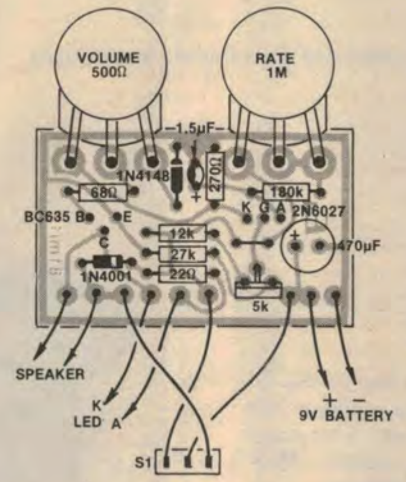
1 470μF 10 volt PC electrolytic
1 1.5μF 16VW tantalum electrolytic

RESISTORS

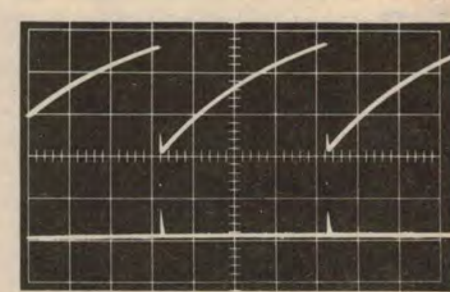
(¼ watt, 5% carbon film)
1 x 180kΩ, 1 x 27kΩ, 1 x 12kΩ, 1 x 270Ω, 1 x 68Ω, 1 x 22Ω
1 1MΩ linear potentiometer
1 5kΩ vertical mount trimpot
1 500Ω linear potentiometer

MISCELLANEOUS

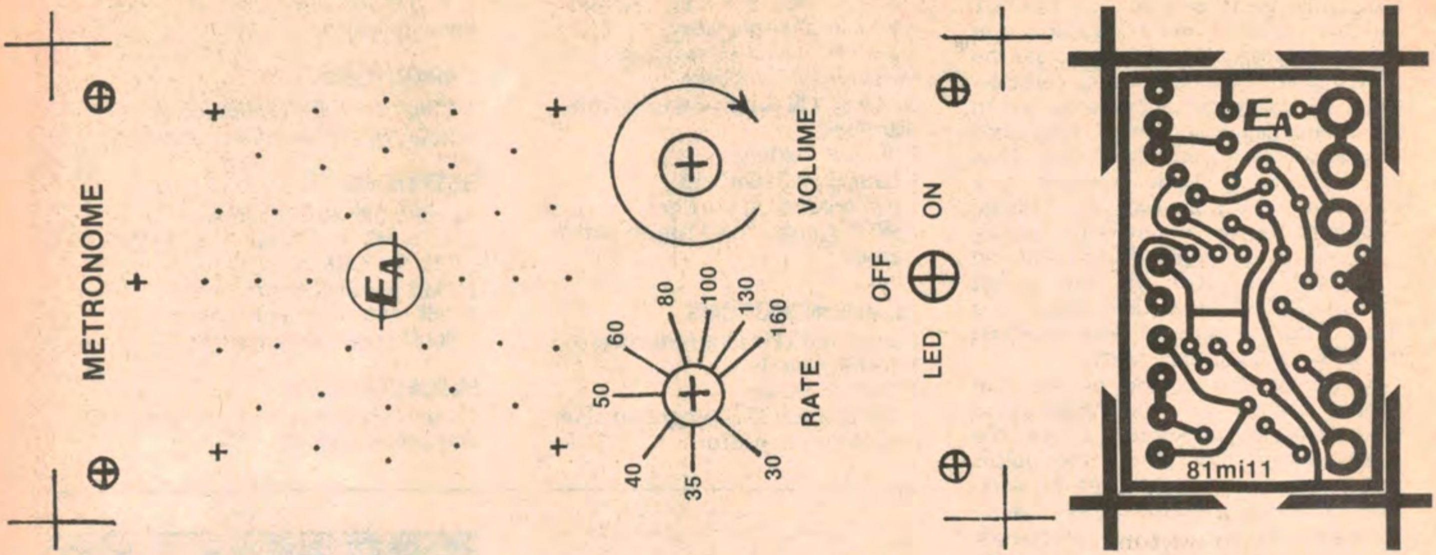
1 metre hook-up wire, screws, nuts and solder lugs etc.



LEFT: the component overlay diagram. The volume and rate potentiometers are soldered direct to the PCB.



This photograph shows the waveform at the anode and cathode of the PUT.



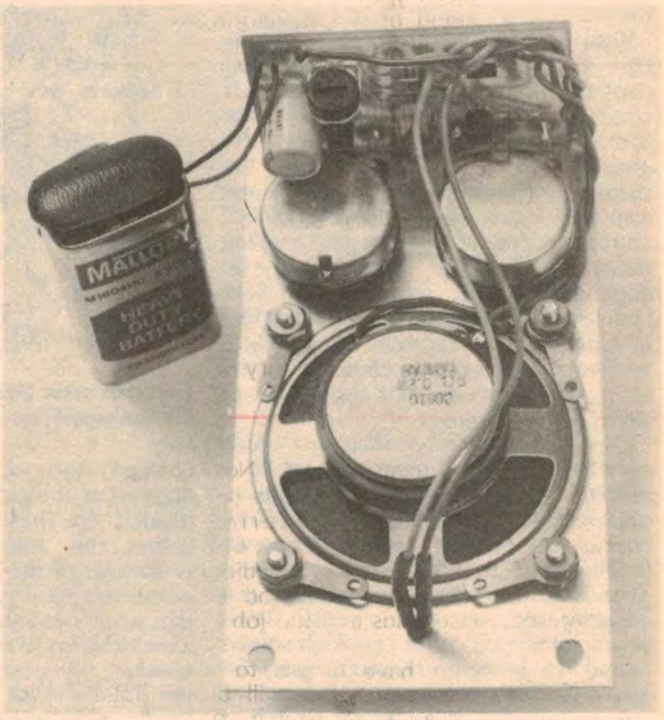
Here are actual size artworks for the front panel and the printed circuit board.

between each click, the 470μF capacitor was able to charge via the LED and loudspeaker, since the transistor was turned off. Then, when the transistor turned on, ostensibly only to light the LED, the capacitor was able to deliver a pulse of current to the loudspeaker. Very tricky! Therefore, the capacitor now resides permanently connected to the battery. The leakage current of the capacitor, by the way, can normally be expected to be around one microamp or so, which is hardly likely to reduce the battery life by a significant amount.

Current drain of the unit varies with volume control settings; at minimum setting only the PUT oscillator is functional, drawing some 220μA. At 120 beats (crotchets) per minute the average current consumption is around 850μA with the volume turned to maximum, and the metronome simultaneously driving LED and loudspeaker.

Having considered the operation of the circuit, let us now turn to its assembly.

View of the completed PCB and front panel assembly. Note how the loudspeaker is secured.



CONSTRUCTION

Our unit was built into a small plastic zippy box measuring 68(W) x 130(H) x 41(D)mm. The printed circuit board is coded 81mi11 and measures 57 x 35mm.

Commence construction by assembling the components onto the PC board. Install smaller components first, finishing with the capacitors and transistors. Follow the overlay provided to assist in the orientation and positioning of the components. Make sure that polarised items are correctly oriented, and that the resistor and capacitor values are as per the circuit. At this stage do not solder the potentiometers to the board.

The next step is to affix the self-adhesive Scotchcal label to the front panel, and drill the holes for the controls and loudspeaker.

Straighten the connecting lugs of the potentiometers so that they lie at right angles to the pot shafts and can be fed into the appropriate holes on the PC board. Note that it will probably be necessary to slightly crimp the ends of each lug to enable them to pass through the 3mm diameter holes in the PC board.

Now install the two potentiometers in the front panel, remembering that the 1MΩ pot is used for the Rate control, and the 500Ω for the Volume control. Ensure that the pots' connecting lugs are positioned to face towards the lower edge of the panel. Fit the assembled board to the pot lugs, and solder together.

The toggle switch, LED and loudspeaker may now be fitted to the panel. Note that four solder lugs, each secured with a screw and two nuts, hold the loudspeaker in position.

Wire up the LED, switch, loudspeaker and battery clip leads to the PC board, as per the component overlay diagram. Connect the battery, and switch the unit on. Providing the volume control is partly advanced, you should hear clicks at a rate set by the Rate control. Advance the Volume control further and check that the LED is flashing in time with the audible clicks. Switch to LED only, noting that the LED continues flashing but the clicks are suppressed.

Assuming that your metronome is functioning as described above, you can now calibrate the Rate control. Firstly, fix its knob so that it can rotate equally past the 30 and 160 marks. There should be about 10 degrees of rotation past both marks. As this is a relatively simple instrument, we have only included a preset for adjusting the basic rate, and have omitted facilities for presetting end limits for the Rate control. Thus the "tracking" of the Rate control on your unit will be dependent on the tolerance match of the 1MΩ potentiometer and associated series 180kΩ resistor. For this reason it is desirable to perform the calibration at a rate which is in the centre of your most used range.

There are two ways to calibrate your metronome. First, if you have a frequency meter which can measure period (the latest EA design described last month is ideal) you can use it to measure the period of the waveform. Connect the frequency meter across the 270Ω cathode load resistor for the PUT and set the frequency meter mode control for period measurements. Now set the rate control for 100 beats per minute and note the period measurement. It should be 600 milliseconds or not far off. Now adjust the 5kΩ trimpot to get a period of exactly 600 milliseconds and the job is complete.

We estimate that the current cost of parts for this project is approximately

$17.00

including sales tax and battery

Should you not have access to a suitable frequency counter, it will be necessary to use a stopwatch or wristwatch with sweep second hand. As previously, set the pointer to "100", turn the metronome on and count the clicks in, say, a one-minute period. Adjust the preset to obtain exactly 100 clicks (Hint: for coarse adjustment, count the clicks in, say, a 12-second period – should be 20 clicks – then use the one-minute period for the final fine adjustment).

The unit may now be screwed into its box, and is ready for use. One final thought: readers interested in photography can set the Rate control to 60 (one click per second), and use the audible clicks to tick off the seconds for "time" exposures at night or for printing sessions in the darkroom.