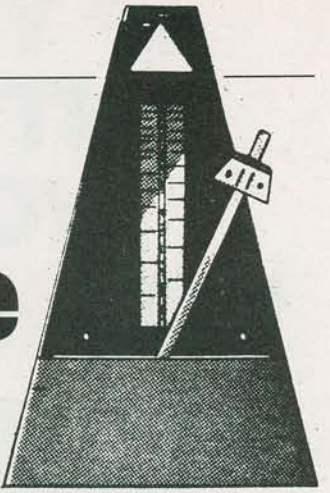
Accented Beat Metronome



Keep time with this simple, inexpensive metronome

By Robert Penfold

Although purely electronic, the Accented Metronome is a modern equivalent to the traditional pendulum style mechanical type and has been designed to give the same sort of "click" sound to indicate each beat.

Some mechanical metronomes also have a bell which can be used to give an accented beat and this unit has a similar facility. This is in the form of an additional circuit which enables a longer and deeper "thud" sound to be used to accent anything from every second beat to every tenth beat. The accentuation can be switched out altogether when it is not required.

The unit also has a bargraph display which gives a visual indication of the beat sequence, and is the equivalent of being able to see the pendulum of a traditional metronome. However, the ten LED bargraph shows exactly which beat is the current one in the sequence, even when, say, only every sixth or eighth beat is accentuated.

The unit is self-contained with power being provided by an internal 9V battery, and it is quite simple and inexpensive despite the fact that it provides both an accented beat facility and an LED display. It covers a wide beat range of around one every two seconds to about five per second.

System Operation

A clock oscillator, two monostable multivibrators and a digital divider circuit form the basis of the metronome, as can be seen from the block diagram of Fig. 1. The clock oscillator is a low frequency type which has its output frequency made adjustable by means of variable resistor. The frequency range covered by the unit governs the beat rate range of the metronome, and is therefore about 0.5Hz to 5Hz.

The output of the clock oscillator drives the input of a monostable multivibrator. The direct output of the oscillator is less than ideal for driving the loudspeaker as it is virtually a squarewave signal, whereas a short pulse signal is needed to produce each "click" sound.

The monostable is a non-retriggerable type which acts as a pulse shortener, and provides and output pulse of suitable duration regardless of how long the input pulse duration happens to be. The output pulses from the monostable are fed into a mixer circuit, and from here they are coupled to an output stage which provides the fairly high drive current needed to get good volume from the loudspeaker.

This gives the basic metronome function, but some extra stages are needed in order to give the accented beat facility. The main one of these is a divide by "N" counter, and this has a division rate which under switch control can be set to any integer from two to ten.

The output of the divider drives a second monostable multivibrator, but obviously this monostable will only be triggered on every second clock cycle, third clock cycle, or whatever the selected division rate dictates. The output pulses from this second monostable are mixed with the signal from the first one, but as the loudspeaker is already driven with the maximum output current that the output stage can provide, this does not in itself provide any significant accentuation of the basic "click" sounds.

The accentuation is provided by having the output pulse duration of the second monostable several times longer than the pulse length of the first one, so that the accented beats are indicated by what are really longer output pulses. These are perceived by listeners as deeper sounds which have an apparently higher volume level, and which are clearly distinguishable from the ordinary "click" sounds.

Display

The divider circuit has ten outputs which can be used to directly drive the bargraph display, and no special decoder or driver circuit is needed here. In fact the display is not a true bargraph type, which would have the first LED lit to indicate the first beat, LEDs one and two switched on to indicate the second beat, and so on.

This display operates in what is generally known as the "dot" mode, where the first LED. lights up to indicate the first beat, the second LED, (and only the second LED) switches on to indicate the second beat, the third LED turns on to mark the third

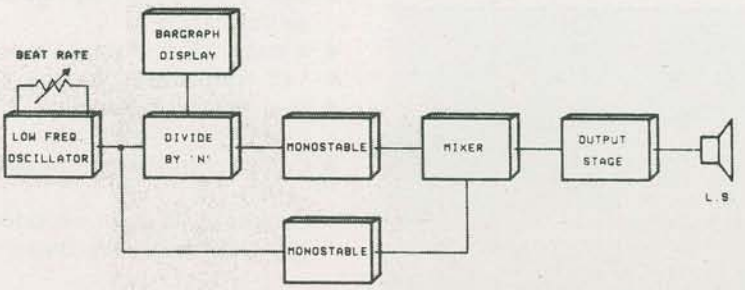


Fig. 1. Block diagram showing arrangement used in the Accented Beat Metronome.

beat, and so on. A "dot" type display perhaps gives a slightly less clear indication, but it is the only type that can be easily used with the driver circuit available in this case, and it also has the great advantage of providing the unit with a much lower level of current consumption.

Circuit Operation

The complete circuit diagram of the Accented Metronome appears in Fig. 2.

A 555 astable circuit generates the clock signal, but in order to keep the current consumption of the circuit down to an acceptable level a low power version of the 555 such as the 7555 is recommended for IC1. Potentiometer VR1 is the frequency control, or the Beat Rate control as it should more correctly be called in this case.

The timing capacitor C2 should be a tantalum bead component. An ordinary electrolytic type capacitor is considerably less than ideal for this application where the poor tolerance rating could give a frequency range which was well away from the desired one, and the high leakage level could result in even worse frequency accuracy or even the circuit failing to oscillate at all at the low frequency end of the range.

Both monostables are based on two of the CMOS 2-input NOR gates of IC3 and use what is a standard configuration. IC3a and IC3b have capacitor C3 and resistor R4 as their timing components, and the approximate output pulse duration is 0.2 milliseconds. This gives the higher pitched "click" sound. IC3c and IC3d have C4 and R6 as their timing components, and with an output pulse duration of about 0.8 milliseconds or so this gives the lower pitched "thud" sound.

The two sets of output pulses are mixed by resistor R7 and R8 which form a simple passive mixer circuit. The pulses drive TR1 hard into conduction so that a heavy but brief current is driven through the loudspeaker LS1.

The peak power level fed to the loudspeakers is actually quite high and constitutes a considerable overload, but as the output pulses are very brief and infrequent the average power fed to LS1 is quite low, and there seems to be no danger of it being damaged. A high impedance (about 64 ohm) loudspeaker would appear to be better suited to this type of output stage, and although loudspeakers of this type will work quite well in the circuit, they provide a substantially lower volume level than low impedance types.

Divider

The divider IC2 is a CMOS 4017BE, which is a decade counter and one of ten decoder. In this case the ordinary divide by ten ("carry out") output at pin 12 is of no interest and is ignored. It is the other ten outputs that are of use, and these are numbered from "0" to "9".

When the device is reset, output "0" goes high and all the other outputs take up the low state. On the next clock pulse output "0" goes low and output "1" assumes the high state. The next clock pulse takes output "1" low again and sets output "2" high.

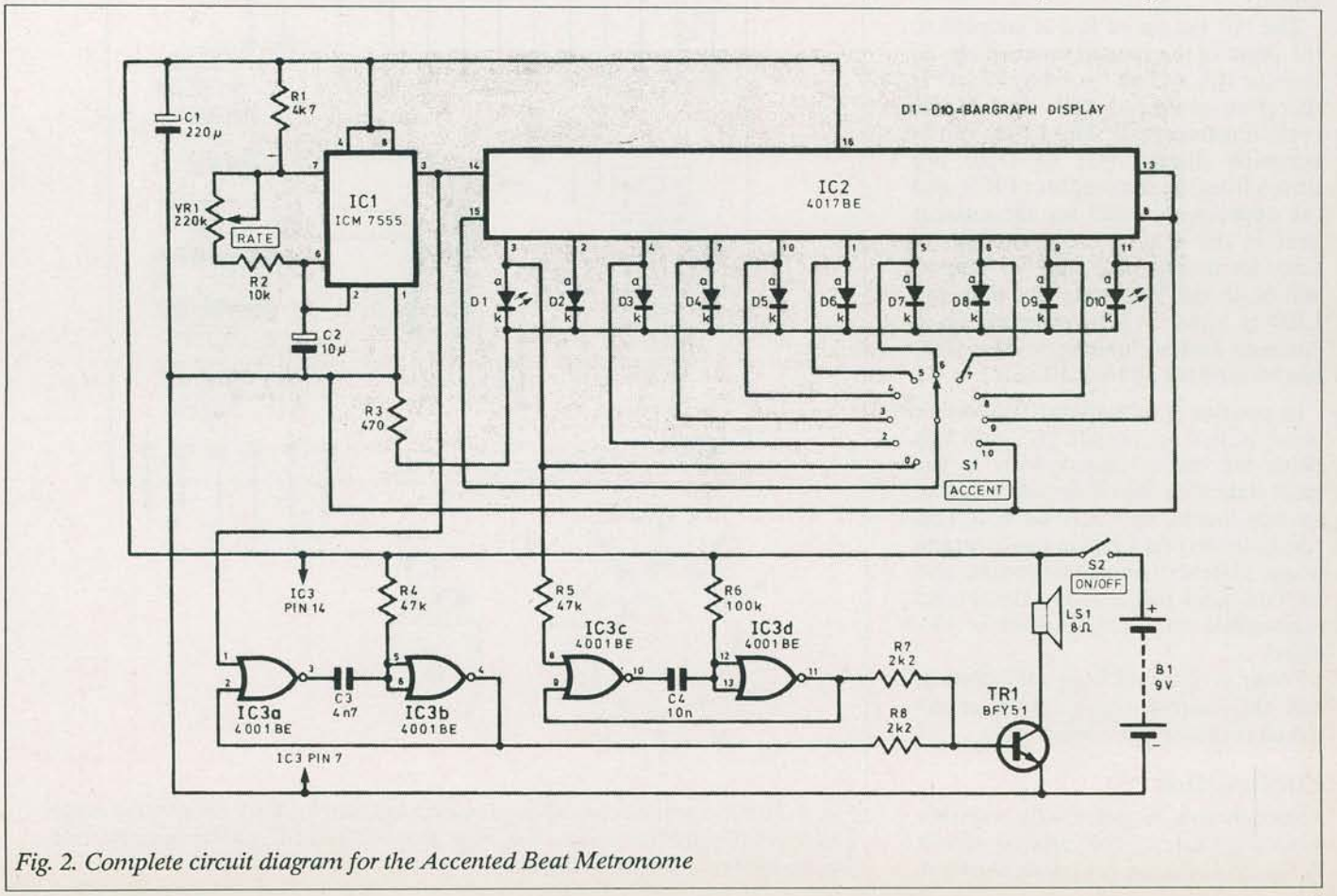


Fig. 2. Complete circuit diagram for the Accented Beat Metronome

This sequence of events continues until output "9" goes high. In the next clock pulse output "9" returns to the low state and output "0" goes high again. This takes things back to the beginning again, and the device cycles indefinitely in this manner.

At least, it does if it is allowed to. In this circuit the Reset input at pin 15 of IC2 is coupled by switch S1 either to one of the outputs, or in the tenth position it is simply tied to the 0 volt rail. It is therefore only in position 10 of switch S1 that IC2 provides the standard divide by ten action. In the other switch positions at some stage in the sequence the output to which the reset input is connected will go high, and IC2 will immediately be reset to the initial state where output "0" is high.

For example, in position 2 output "0" will go high in the normal way, followed by output "1" on the next clock cycle. However, when output "2" goes high IC2 is reset and output "0" goes high again. A divide by 2 action is therefore obtained, and by selecting the appropriate switch position any division rate from two to ten can be obtained.

The "0" output of IC2 is coupled to the input of the second monostable via resistor R5, and an "accented beat" is therefore produced each time a new cycle recommences. The LEDs of the bargraph display (D1 to D10) are driven from the ten outputs of IC2, and the appropriate LED for the current beat in the sequence is switched on since its output, and only its output, will be in the high state. As only one LED at a time will be switched on, a common current limiting resistor (R3) can be used for all ten LEDs.

In position 0 of switch S1 the reset input is tied to output "0", and this holds the device permanently in the reset state with the clock pulses consequently having no effect on IC2. This results in the first LED in the bargraph being switched on continuously, and with no input pulses fed to the second monostable the accentuation is disabled.

Power is obtained from a 9V battery, and the current consumption of the circuit is only about 8 milliamps.

Construction

Although this is potentially a rather awkward project, the printed circuit design and component layout shown in Fig. 3 helps to make matters much more straightforward.

Construction of the board is not difficult, but bear in mind that IC2 and IC3 are both CMOS types, and that the normal anti-static handling precautions should be observed when dealing with these. This basically means using integrated circuit holders for these components, and not fitting them into place until the unit has been completed in all other respects.

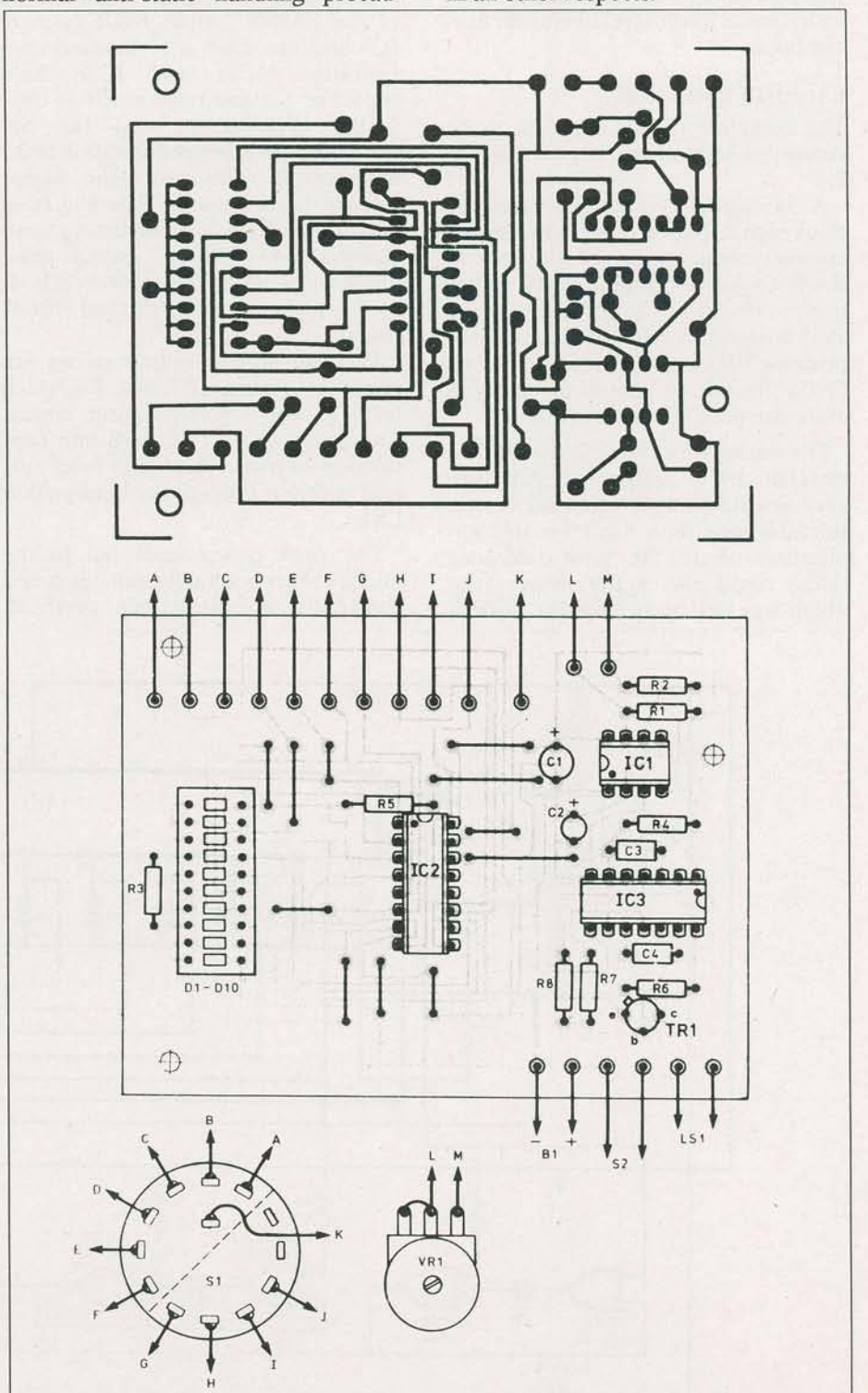


Fig. 3. Full size printed circuit board master foil pattern (top), component layout and interwiring for the metronome. Note that a 20-pin DIL socker must be used for mounting the bargraph display.

Until then they should be left in their antistatic packaging (plastic tubes, conductive foam, or whatever) and they should he handled as little as possible when it is time to plug them into their holders. Avoid getting them anywhere near any obvious source of strong static charges.

Although IC1 is also a CMOS device, it does not require any special handling precautions as it has very effective internal protection circuits which render them unnecessary. As the 7555 integrated circuit is very inexpensive, it is recommended that an IC holder is used for IC1.

It is assumed in Fig 3. that the bargraph display is of the type which has a 20-pin DIL package, and this will plug straight into a 20-pin DIL integrated circuit holder mounted on the board. This socket is not just needed to prevent possible heat damage to the device when fitting it into circuit, but is also required to physically raise the display to as more suitable height. The socket should *NOT*, therefore, be omitted.

With this type of display there usually seems to be nothing to indicate which way it should be fitted, but if necessary the correct orientation can be found by trial and error, and the display will not sustain any damage if it is fed with power of the wrong polarity.

Of course, if preferred the bargraph display can be formed from ten ordinary panel mounting LEDs fitted on the front panel of the unit, and this could actually give a much clearer display. On the other hand, it would increase the amount of hard wiring required and would make construction of the unit much more difficult.

Case

The case used for the prototype is a plastic type having an aluminium front panel and approximate outside dimensions of 205mm by 145mm by 40mm. The unit could actually be fitted into a much smaller case if desired, although this might necessitate the use of smaller loudspeaker with a consequent reduction in volume, and it could prove difficult to mount the printed circuit board in a way which brings the display into a suitable position.

Assuming that the metronome is built along the same lines as the prototype, the three controls are mounted on the front panel and the loudspeaker is fitted towards the left-hand side of the top panel or case "lid".

A speaker grille of some kind is needed, and the most simple way of producing one of these is to drill a matrix of holes about 5 millimeters in diameter. Be very careful with the placement of the holes though, as it is not quite as easy to make a neat job of this as one might think.

Miniature loudspeakers rarely have any provision for screw fixing, and it is normally necessary to glue them in place. Any good general purpose adhesive will do, but try to avoid smearing any onto the diaphragm.

The printed circuit board is mounted on the base panel towards the right-hand side of the unit, and it is mounted on spacers which give a stand-off about 20 millimeters from the base panel. This is to bring the display to a suitable height, so that it is immediately underneath a display window cut at the appropriate position in the top panel of the case.

The rectangular cutout can be made using a coping saw or a fret saw. A piece of red display window material is glued in place behind the cutout.

To complete the metronome the hard wiring is added, and this shown in Fig. 3. The wiring from the board to the Rate control (VR1) and the Accent switch (S1) is carried out by wiring from point "A" to point "A" and then the two point "B"s are connected together, and so on. Ordinary multistrand connecting wire is used and there should be no real difficulty here provided the pins, component tags, and the ends of the leads are properly tinned with solder prior to making each connection.

There is ample space of the battery, and this can be held in place with a double-sided adhesive pad. If six 1.5V batteries in a holder are used, a standard 9V style battery clip is needed to make the connections to the holder.

In Use

Give the finished unit a thorough check for errors before switching it on and testing it. Once switched on it should produce a regular "clicking" sound at the rate controlled by VR1, and by setting S1 to introduce the accentuation the appropriate sounds and responses from the display should be obtained. If there is any sign of a malfunction, switch off at once and recheck all the wiring.

If the metronome is to be adjusted "by ear" there is no need to mark a scale around the control knob of VR1, but many users will require some sort of beat rate scale. There is no real difficulty in finding calibration points by counting the number of beats in a certain period of time, and using trial and error to fine tune VR1 to the correct settings. These can then be marked using rub-on transfers.

It can be difficult to make a really accurate scale as the calibration points tend to become cramped at the high frequency end of the range. This problem can be eased by using a "logarithmic" potentiometer for VR1 and connecting it in reverse so that clockwise adjustment gives a reduction in the beat rate. This gives something approximating to a linear scale but it is reverse reading of course.

Using a large control knob also helps to space out the calibration points and make precise adjustment easier.

Parts List

Resistors (All 1/4W, 5% carbon)

R1	4k7
R2	10k
R3	470R
R4,5	47k
R6	100k
R7,8	2k2

Potentiometer

VR1	220k

Capacitors

C1	220u radial 10V elect.
C2	10u 16V tantalum bead
C3	4n7 polyester
C4	10n polyester

Semiconductors

IC1	7555 CMOS Timer
IC2	4017 decade counter
IC3	4001 quad 2-input NOR
TR1	2297 npn silicon
D1-D10	10 LED bargraph

Miscellaneous

S1	12-way, 1-pole rot. with stop
S2	Sub-min SPST toggle
LS1	8 ohm loudsp. 76mm diam.

Case: 250mm x 145mm x 40mm; PCB; 8-pin, 14-pin, 16-pin, and 20-pin DIL IC holders; 9V battery and clip; red display window material; 2 control knobs; solder pins; wire; stand-offs etc.

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