An audible voltmeter and bridge-indicator

"Bellbird" — an aid for the blind

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Most of us will realise how much we owe to our eyes in the pursuit of our electronics profession or hobby. We may feel that blindness would completely end our participation in such activities, but this is wrong, as many blind radio amateurs have proved. However, there are many difficulties and a major one is the making of measurements. Various methods have been devised to enable the blind to read moving-pointer instruments, and most of these use photocells and buzzers. There are also null-type instruments with large dials labelled in Braille, but these are slow and inconvenient. Modern digital methods seem to offer the answer.

Clive is a seventh-form physics student who has been blind from birth. His hobby is electronics and he builds all sorts of things, relying on written descriptions of the circuits. Sometimes he is helped by having an integrated circuit mounted on a larger printed circuit board as a sub-mount, but apart from that he is self-reliant. It was with Clive in mind that a rather old digital voltmeter (using r.t. logic) was bought with the idea that it could be used to give an audible output. The meter could be used not only in his hobby activities but also in his 7th form physics experiments and later in his university studies.

The voltmeter is conventional in that it has three digits with an over-range 1 and an automatic polarity indication. Overloading results in blanking and an X display on a Nixie tube. It seemed that the problem was that of converting the parallel display, where all the digits are seen at once, to a serial presentation, where only one figure is seen at a time. I believe that a device which announces the digits orally is available, but this is expensive and difficult for the lone worker to make. The information inside the voltmeter is, of course, in binary form and there seemed to be no reason why this should not be suitable for direct communication with the user, if translated into suitable sound and presented bit by bit. There are several possibilities: changing note length, note pitch, or note quality. The first method is used in Morse code but would possibly be confusing in this new application, unless the five-bit Morse numerals themselves were used. These are rather cumbersome and would present difficulties in decoding. The translation of a binary 1 into a high pitched note and a 0 into a low pitched note seems natural and has proved acceptable in practice. If the X, +, — and over-range 1 can be combined into one digit then we have four 4-bit digits to convey, in addition to the decimal point, which suits the capability of a 16 to 1 multiplexer very well. This, as many will know, is an i.c. with an output which can take up the state of any one of sixteen inputs, as selected by the binary number on four address pins. It was found possible to invent a simple code for the prefix digit, thus:

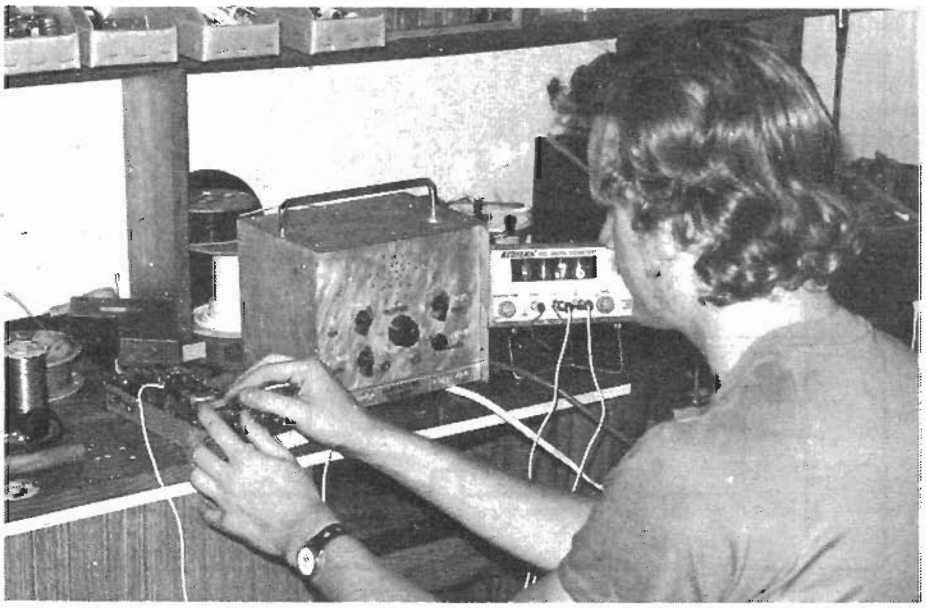
+0	1	1	0	0
−0	1	0	1	0
+1	1	1	0	1
−1	1	0	1	1
X	1	1	1	1

All of these are binary numbers greater than 9, so there is no possibility of confusion with other digits.

The multiplexer is made to select each of its 16 inputs in turn by means of a binary counter connected to its address pins. The counter is operated by a multivibrator (two monostables) working continuously.

We now come to a point where two distinct design approaches are possible. There must be pauses between the digits, a long pause at the end of each reading, and extra pauses to enable a brief "decimal point" pulse to be inserted at the correct point between digits. These delays can be provided either by monostables, which switch off the counter for a period, or they can be arranged to span a given number of counter pulses. The latter method uses a fully digital system. There are advantages and disadvantages to each system, but I was attracted by the simplicity and flexibility of the monostable method because it was difficult to know in advance the exact time intervals required, and monostables offer simple and almost infinite adjustment.

The tone frequencies are provided by an LM566 voltage-controlled oscillator, the output from which is amplified by



Measuring instrument being used by Clive, an electronics hobbyist who has been blind from birth.

an LM380 2½ watt amplifier. The frequencies generated by this device depend upon the input direct voltage and the value of a capacitor connected to the i.c. It seemed to be wasteful merely to use this versatile component to give two pitches, and a circuit was devised so that the instrument could also be used for an entirely different purpose, as a bridge null-detector. In the latter application the suitably amplified out-of-balance voltage from almost any bridge circuit is used to alter the frequency. (A bridge rectifier circuit gives a rise in pitch for both positive and negative input voltages.) In the digital application a fixed voltage is switched in and the multiplexer is used to change the capacitor values.

Clive had no difficulty in learning the code. A speed control was fitted, and it was not long before new timing capacitors had to be provided to allow him to work faster. The rather strange warbling note gave rise to the name "Bellbird," bearing some resemblance to the song of that New Zealand bird.

I consider that sighted workers may have a use for such a machine, as it enables one to concentrate on the circuit under test instead of dividing attention between that and a meter reading.

Circuit description

For clarity, the digital circuit diagram (Fig. 1) omits power supplies, irrelevant connections, and timing resistors and capacitors. The various delay i.c.s are all type 74121, though dual devices could be used. Doubtless improvements could be made, not least of which would be the avoidance of "glitches" caused by race conditions, which are the reason for small capacitors on the A inputs.

Monostables X and Y, operating as a multivibrator, cause the binary counter 7493 to select each of the voltmeter digits in turn to be presented at gate G. The OR gates A provide the prefix code already discussed. The action of the multivibrator is interrupted by gate D,

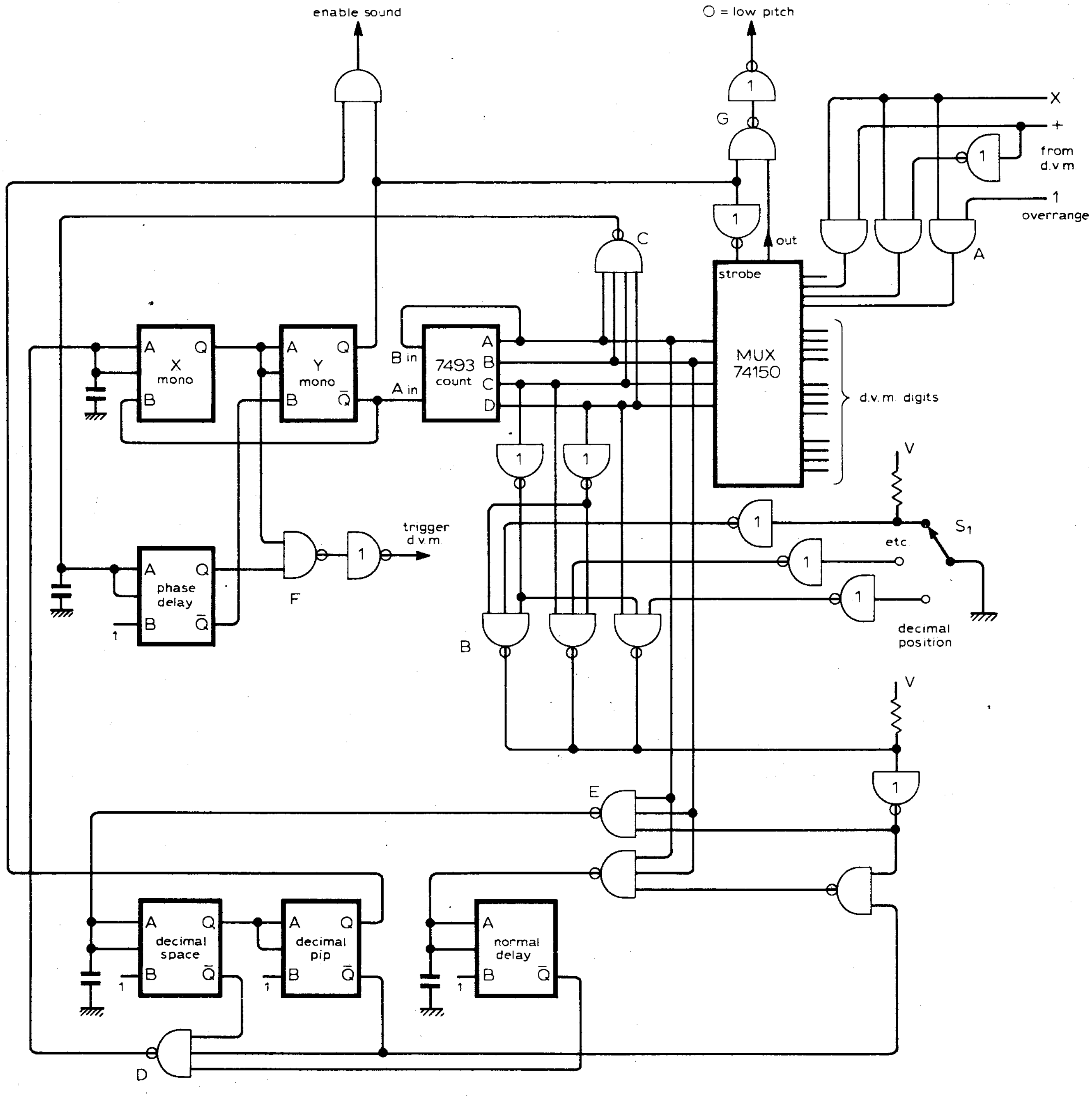
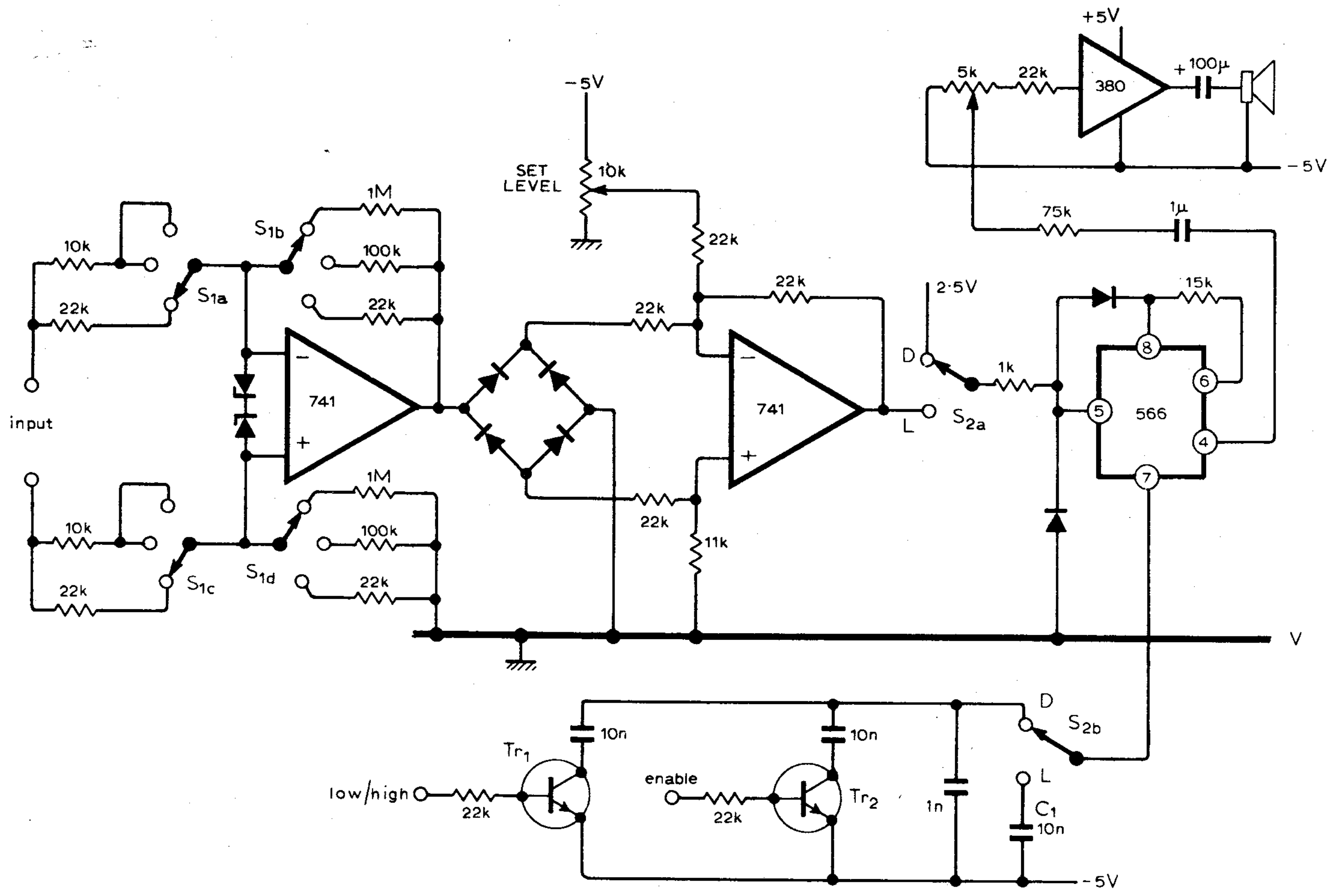


Fig. 1. Digital circuits for translating a measured voltage, represented by the digits within the digital voltmeter, into a series binary code suitable for triggering a circuit (see Fig. 2) to produce audible low/high pitches. Spaces between numbers and readings are also produced by these circuits, together with a decimal point when required.



which operates whenever the "decimal space" "decimal pip" or "normal delay" monostables fire. Gates B control these in the following way: with S_1, the decimal point switch inside the voltmeter, in the position shown, the wired-OR output from gates B goes to logical 0 on a count of C = 0, D = 0. In the mid position the output goes to 0 on C = 1, D = 0 and in the bottom position on C = 0, D = 1. The A and B lines of the counter output are connected, as well as the inverted B gates output, to gates E. It will be seen that the upper gate fires the decimal-point delay on a count of 0011, 0111 and 1011 in the three switch positions mentioned. This will put the decimal delay after the prefix, first or second digits respectively. When the decimal delay monostable finishes its pulse it triggers the decimal-pip monostable, which takes over the job of arresting X and Y and sends a signal to the sound enable gate.

The lower gate E is operated, giving normal delay, whenever the A and B lines are high and the B gates output is also high, provided that the decimal-pip monostable has not fired. This means that it is triggered at the end of digits when the decimal point signal is not given. At the end of the whole cycle or phrase a count of 1111 forces the output of gate C low, thus firing the phrase-delay monostable and operating gate F to send a trigger signal to the voltmeter, which luckily has provision for this external control of its cycle. It is possible that spurious readings would be obtained with some meters if the outputs were multiplexed while they were half way through their cycle. In the Bellbird system the digital voltmeter measures only between phrases.

Fig. 2. Bridge-indicator and sound circuit. Switch positions D enable the circuit to be used in the digital voltmeter mode, the v.c.o. LM566 producing a low pitch for an input binary "0" and a high pitch for an input binary "1". Switch positions L enable the circuit to be used as a bridge null-detector, the null point being at the point of lowest pitch.

It will be noticed that if there is no connection at S_1 no decimal point indication is given.

Bridge indicator and sound circuit

Referring to Fig. 2, S_{2a} connects the input of the voltage controlled oscillator to either the amplified out-of-balance voltage or to a fixed 2.5V potential, to give the two modes of operation. At the same time S_{2b} connects the oscillator to either C_1, for linear operation, or a circuit controlled by Tr_1 and Tr_2 for the voltmeter application. Safety diodes protect the LM566 from negative inputs, which could result from failure or wrong connections in the previous circuits. Two type 741 operational amplifiers perform the tasks of amplifying input signals with gains of 1, 10 and 100, selected by S_1, and adjusting the d.c. output level to give a suitable range of tone. The input to the first 741 is protected by two 5V zener diodes. A rectifier bridge ensures that when the output from the first 741 goes either positive or negative from zero the oscillator input voltage, and therefore the tone, will rise. This bridge should be constructed with germanium diodes to avoid a large "dead zone" caused by the higher forward voltage of silicon types.

The switching circuit enables one or two capacitors to be connected to the oscillator, giving high and low audible tones.

The audio circuit is as simple as possible: the a.c. component from LM566 is attenuated by a volume-control potentiometer before being fed to the LM380 amplifier. The loudspeaker coupling capacitor need not be of a high value since no low tones are required.

In use no special difficulties were noted. In linear operation the null point was obtained by listening for the point of lowest pitch. Greater sensitivity was obtained by adjusting S_1 and 1mm discrimination could easily be obtained on a metre bridge experiment. In the digital mode, as already noted, the learning process was fast. Sighted pupils were also interested, and as they had already some knowledge of binary code they were able to translate for themselves, though at a slower rate. After practice, of course, recognition of the "digit pattern" occurs, as with Morse code.