Tag!

a strenuous game can be played without physical effort

One of the simpler games known to man is 'Tag'. Variations of the game were probably played by cave-men. There are very few rules: it is simply a question of one person being 'him' or 'it', and running around trying to 'catch' or 'tag' the other player(s). What the game lacks in sophistication, it makes up for in sheer physical strenuousness. In its basic form it is not really a parlour game, either; the risk of toppling tables, falling flowers and the cat in the curtains is more than most parents are prepared to take. Since the main characteristics of the coming months are snow, sleet and Santa Claus, a safe, indoor version of the game should prove welcome.

Figure 1. Block diagram of Tag. As the two players operate their control potentiometers, the course of the game is apparent from a fascinating variety of optical and acoustical indicators.

Figure 2. The complete circuit.

Instead of running like mad, the two players of the electronic version of tag merely twist the knob of a potentiometer madly to and fro. The rules are as simple as in the original game: player 'A' attempts to manipulate his knob in such a way that the pointer of a multimeter moves out of a small area around mid-scale; player 'B' does his utmost with *his* knob to keep the pointer within the area. In other words, player 'A' tries to 'run away', and player 'B' tries to catch him. If 'B' is successful, in that he succeeds in tracking 'A' for a sufficient length of time, a LED lights to indicate that 'B' has 'caught' his opponent.
To increase the effect, sound effects are included: the player controls also sweep two oscillators up and down. The outputs from these oscillators can be fed to the two channels of a stereo amplifier, producing penetrating wails that sweep up and down through the audio range.
The block diagram (figure 1) illustrates the basic principles involved. The control potentiometers 'A' and 'B' provide voltages u_A and u_B. The difference voltage $u_B - u_A$ is determined, and added to half the supply voltage U_b. The result is a voltage u_M which swings to and fro around $½U_b$, depending on the values of u_A and u_B. This voltage is displayed on the multimeter. Obviously, if the two potentiometers are in the same position the difference voltage $u_B - u_A$ will be zero, and the meter will read mid-scale (assuming that full-scale corresponds to the full supply voltage).
If player 'A' now 'runs away', turning his knob in such a way that u_A decreases, the pointer will move to the right. Player 'B', seeing this, counters by twisting his knob in the same direction, causing the pointer to swing back toward mid-scale.
A further optical indication is provided by means of two LEDs. The voltage u_M is fed to a 'window comparator'. This part of the circuit is discussed in detail elsewhere in this issue (see 'Pocket Bagatelle'). For the present application it is sufficient to know that the output voltage u_C from the window comparator is logic zero as long as the input voltage u_M remains within the voltage 'window', and becomes logic 'one' as soon as u_M is outside the 'window'. In other words, since the voltage window is a small range around half supply voltage, u_C is logic zero as long as the pointer reads approximately mid-scale, and becomes logic 1 if the pointer moves out of this area. As soon as this happens, a LED lights ('escaped'). If player 'A' succeeds in catching 'B' again, the LED will extinguish. If 'A' can now 'hold on to' player 'B' for a sufficient length of time (determined by an RC-network) a different LED will light: 'Gotcha!'
The two VCO's are driven direct from the player control voltages, u_A and u_B. If the outputs from these oscillators are fed to the two channels of a stereo amplifier, an audible indication is obtained of the positions of the two controls. If 'A' has caught 'B' – in other words, if the control voltages are equal – the tones produced by the two VCO's will also be (almost) the same.

The circuit

Having understood the basic principles, the circuit itself (figure 2) is fairly straightforward. P1 and P2 are the player controls. The voltages at the wipers can be varied between approximately 3 V and 9 V. The two voltages are fed to the differential amplifier A1. Half the supply voltage ($½U_b$) is available at the R7/R8 junction, and this reference voltage is also fed in at this point.
The output from A1 is the voltage u_M, also shown in the block diagram. The pointer instrument is connected to this point. Two options are available, a built-in milliameter or a normal multimeter, as will be discussed later. The same voltage is also fed to the window comparator, consisting of A2 and A3. The width of the window can be set with P3 ('handicap'). Obviously, a wide window makes it easier to catch the opponent,

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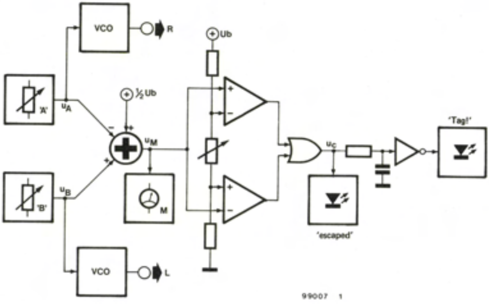
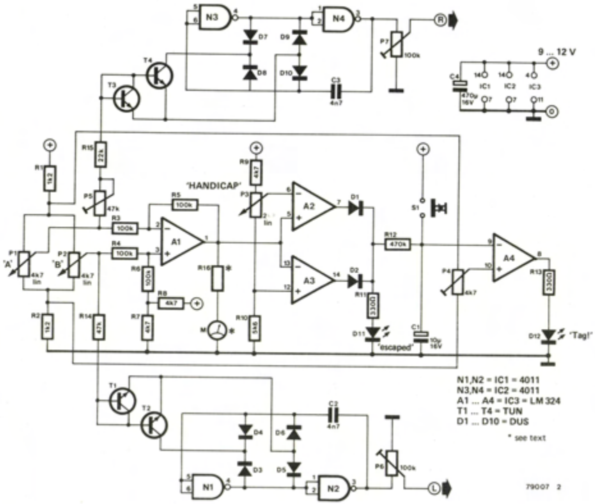

VCO
R
Ub
'A'
u_A
½ Ub
u_M
'Tag!'
'B'
u_B
M
u_C
'escaped'
VCO
L
99007 1

2


N3
N4
D7
D9
D8
D10
T4
T3
C3
4n7
P7
100k
R
9 ... 12 V
C4
470µ
16V
IC1
IC2
IC3
0
R15
22k
R1
1k2
P5
47k
'HANDICAP'
R5
100k
R9
4k7
P3
lin
A2
D1
S1
R3
100k
A1
R4
100k
R12
470k
A4
P1
'A'
4k7
lin
P2
'B'
4k7
lin
R6
100k
R16
*
A3
D2
P4
4k7
R13
330Ω
R8
4k7
R11
330Ω
R2
1k2
R14
47k
R7
4k7
M
*
R10
5k6
D11
'escaped'
C1
10µ
16V
D12
'Tag!'
T1
T2
C2
4n7
D4
D6
D3
D5
P6
100k
N1
N2
L
N1,N2 = IC1 = 4011
N3,N4 = IC2 = 4011
A1 ... A4 = IC3 = LM 324
T1 ... T4 = TUN
D1 ... D10 = DUS
* see text
79007 2

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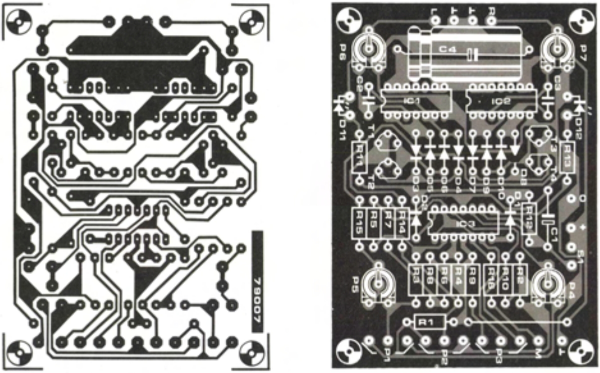

Parts list

Resistors:
R1,R2 = 1k2
R3 . . . R6 = 100 k
R7,R8,R9 = 4k7
R10 = 5k6
R11,R13 = 330 Ω
R12 = 470 k
R14 = 47 k
R15 = 22 k
R16 = see text
P1,P2 = 4k7 (5 k)
linear potentiometer
P3 = 22 k (25 k)
linear potentiometer
P4 = 4k7 (5 k)
preset potentiometer
P5 = 47 k (50 k)
preset potentiometer
P6,P7 = 100 k
preset potentiometer

Capacitors:
C1 = 10 μ/16 V
C2,C3 = 4n7
C4 = 470 μ/16 V

Semiconductors:
D1 . . . D10 = DUS
D11,D12 = LED
T1 . . . T4 = TUN
IC1,IC2 = CD 4011
IC3 = LM 324

Miscellaneous:
S1 = pushbutton, single-pole, make
M = meter, see text

Table

$I_{f.s.d.}$	R16 U_b = 12 V	R16 U_b = 10 V
50 μA	220 k	220 k
100 μA	120 k	100 k
300 μA	39 k	33 k
500 μA	22 k	22 k
1 mA	12 k	10 k
3 mA	3k9	3k3
5 mA	2k2	2k2

and vice versa. The two diodes D1 and D2 are the (wired) OR gate shown in the block diagram. The voltage at the junction of these diodes (u_C) is 'high' when the voltage u_M is outside the 'window', causing D11 to light: 'escaped'.

As long as u_C remains high, capacitor C1 will be charged. If u_C becomes 'low' ('B' has caught 'A'), C1 discharges slowly through R11, R12 and D11. When the voltage on C1 falls below the voltage set by P4, the output of A4 swings high and D12 lights — Tag! The time that 'B' must 'hang on to A' depends on the setting of P4, and can be anything up to a few seconds.

The remainder of the circuit consists of the two VCOs. These circuits may be familiar by now: the modified 'simple CMOS squarewave generator' described in the Summer Circuits issue is also used in 'Ring the bell and win a prize', described elsewhere in this issue. For the first VCO, T1 and T2 are a current mirror and diodes D3 . . . D6 are a bridge circuit. Together, these components are a kind of current-controlled impedance. Since the current mirror is fed through a series resistor, R14, the net result is a voltage-controlled impedance. This impedance is incorporated in a conventional CMOS oscillator circuit in such a way that voltage variations at the input (R14) cause changes in the output frequency. In other words, the complete circuit is a Voltage Controlled Oscillator, or VCO.

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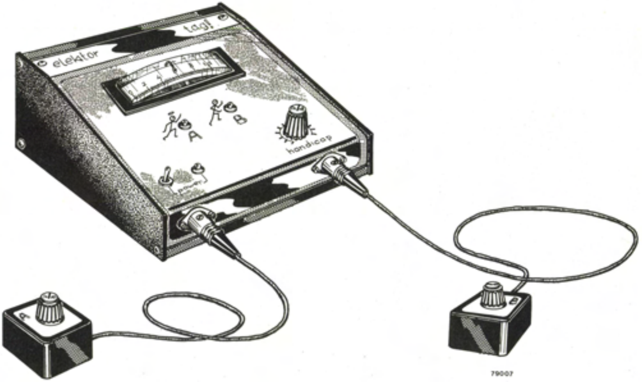

Figure 3. Printed circuit board and component layout (EPS 79007).

Figure 4. The only really important thing about the case is that it should be strong enough! The controls could also be mounted in the main case, but this usually proves awkward unless one of the players happens to be left-handed.

The output level from this oscillator can be set with P6. The second VCO is basically identical, with one minor exception: preset potentiometer P5 is included, so that the 'tracking' of the two oscillators can be adjusted.

Construction

A printed circuit board design and corresponding component layout are shown in figure 3. Although only four NAND gates are used in the circuit, use of a single quad NAND gate IC proved unsatisfactory: the two oscillators tended to 'bite each other'. For this reason, two IC's are used, one for each VCO.

As far as the meter M is concerned, there is a wide range of options. Micro- or milliameters with any sensitivity between 50 μA and 5 mA f.s.d. can be used. In this case, the value of the series resistor R16 is chosen so that the meter reads full scale when the full supply voltage is connected across the series-connection of meter and resistor. The value of the resistor should be approximately:

$$R_{16} = \frac{U_b}{I_{f.s.d.}} \quad (k\Omega),$$

where U_b is in volts and $I_{f.s.d.}$ (the full-scale sensitivity of the meter) is in milliamps. In the interest of saving the batteries in thousands of pocket calculators around the world, the Table lists values for R16 for several common full-scale sensitivities and for two supply voltages. The nearest standard value has been chosen in each case — the meter doesn't have to be a precision instrument!

If a multimeter is available there is no real need to invest in a new meter for this circuit — unless, of course, one is afraid to let that expensive item fall into the hands off one's offspring. If a multimeter *is* to be used, R16 can be replaced by a 1 k resistor — just in case of accidental shorts — and the supply voltage is chosen equal to a suitable voltage range on the meter (10 V f.s.d., for instance).

It is advisable to mount this type of circuit in a sturdy case. The players are liable to get highly excited! Figure 4 is just one possible suggestion. In this case, the two controls are mounted separately and connected to the main unit by means of a standard three-core (mains) cable. ◼