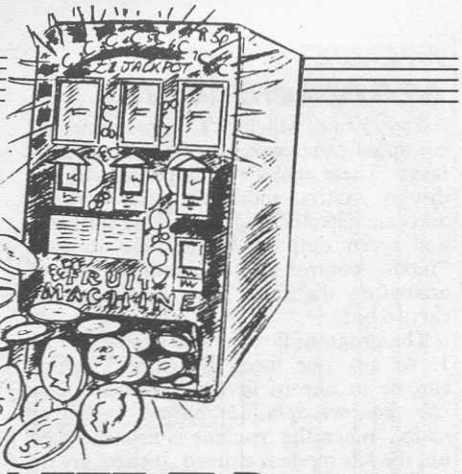
Constructional Project



EPE FRUIT MACHINE

BRETT GOSSAGE and JULYAN ILETT — Part 1

A coin operated fruit machine that really pays out!

HAVING had a keen interest in fruit machines (also known as "slots", "automatics" or "one arm bandits") for as long as the authors can remember, they have always had it in mind to construct one. At a very early age, mechanical designs constructed using Meccano or Lego were attempted, but met with limited success, so an electronic machine was the obvious alternative.

Many years ago, an all TTL system was proposed, but if even the simplest of features were to be included, the circuitry would have been very complex. Some time later, a microprocessor design was considered, but it still would have involved considerable hardware and a hefty power supply.

PAYOFF

Now, finally, a design based around a single chip PIC16C57 microcontroller has become possible, and has resulted in a simple circuit, with battery power capability and plenty of space left for the single most important feature – *a real payout mechanism.*

This design, which it is believed fits into the "executive toy" category, makes use of two simple-to-construct plastic coin mechanisms, a coin detector and a coin payout mechanism. Both mechanisms are designed to work with the new small five pence piece. This coin was chosen for two reasons. First, the Fruit Machine had to be reasonably inexpensive to play while at the same time offering a high value jackpot. Second, since the five pence coin is the smallest, lower value coins will not fit through the slot, so no reject mechanism is required.

ANIMATED FRUIT

In order to minimise the number of mechanical components, large 7-segment displays are used instead of "reels" to reproduce the "fruit" symbols. Animation techniques have been used to give the "reels" a realistic spinning action, and software algorithms have been designed to simulate the inertia and friction of an equivalent mechanical system.

The fruit symbols are passed through the displays from top to bottom, quickly at first, then progressively more slowly until stationary. The three reels have been given different characteristics, so that the left reel stops first, followed by the centre reel and then the right reel.

To add further realism, the sound of the reels clicking against ratchets as they spin has been simulated too. Features including "hold" and "gamble" have been incorporated which appear at random introducing an element of skill into the game.

A mechanical arm, used to start the reels spinning, has been rejected in favour of a "start" button in line with the more up-to-date designs of fruit machine. Naturally, the machine cannot be started until at least one coin has been inserted. Several coins can be inserted if desired, and are registered as "credits" inside the machine.

A set of eight l.e.d.s called the *Feature l.e.d.s* are normally used to indicate the credits but are also used to liven up the machine by flashing various sequences prior to payout and when the machine is not being played.

PAYING OUT

The Fruit Machine has an average payout of about 75 per cent and so is capable of making a profit. Interestingly, commercial machines are bound by law to return a minimum percentage of the stake, typically 70 per cent to 90 per cent, to the player. The exact value is indicated on the front of the machine. Since it does not make commercial sense to payout more than this, the odds are manipulated to maintain this percentage with great accuracy, it does not matter whether you play to win or lose.

This design does not monitor the payout, it is genuinely random and skilful play will increase the payout rate, although never above 100 per cent! For this reason, the Fruit Machine would make an ideal money box for a child who should ultimately discover the futility of gambling!

PROFESSIONAL PRESENTATION

The Fruit Machine is housed in a standard ABS plastic box measuring 220mm × 150mm × 60mm approx. A specially commissioned full-colour self-adhesive front panel is available which considerably enhances the machine's appearance. All the electronics including the displays and switches are mounted on a single sided p.c.b. measuring 100mm × 140mm approx. which is available from the *EPE PCB Service*, code 914.

The specially programmed PIC16C57 microcontroller is available from the authors, price £12, and the colour front panel is £2 (see Shoptalk).

MODE MANAGEMENT

The Fruit Machine's microcontroller continually manages a number of different tasks. These include multiplexing of the display matrix, monitoring the switches and coin detector, and controlling the piezo and servo outputs. In addition to this, "mode" control and the complex task of animating the three reels must also be carried out.

The program flowchart is shown in Fig. 1. At any one time, the Fruit Machine can be in one of seven different modes, *idle, sequence, spin, win, payout, gamble* or *nudge*. When the machine is first switched on, the *idle* mode is entered. If there are no credits, i.e. no coins have been inserted, the machine switches to the *sequence* mode after two seconds to encourage play.

Inserting a coin takes the machine back to the *idle* mode. In this mode, all three reels are stationary, and the program waits for the *start* button to be pressed. If the *hold* feature is active, the three *hold* lights will flash and the *hold* buttons will be active.

When the *start* button is pressed, the machine enters the *spin* mode. Next, a random number generator decides which combination of fruits the reels will stop at. Whether or not a win will be given and its value is decided even before the reels start spinning!

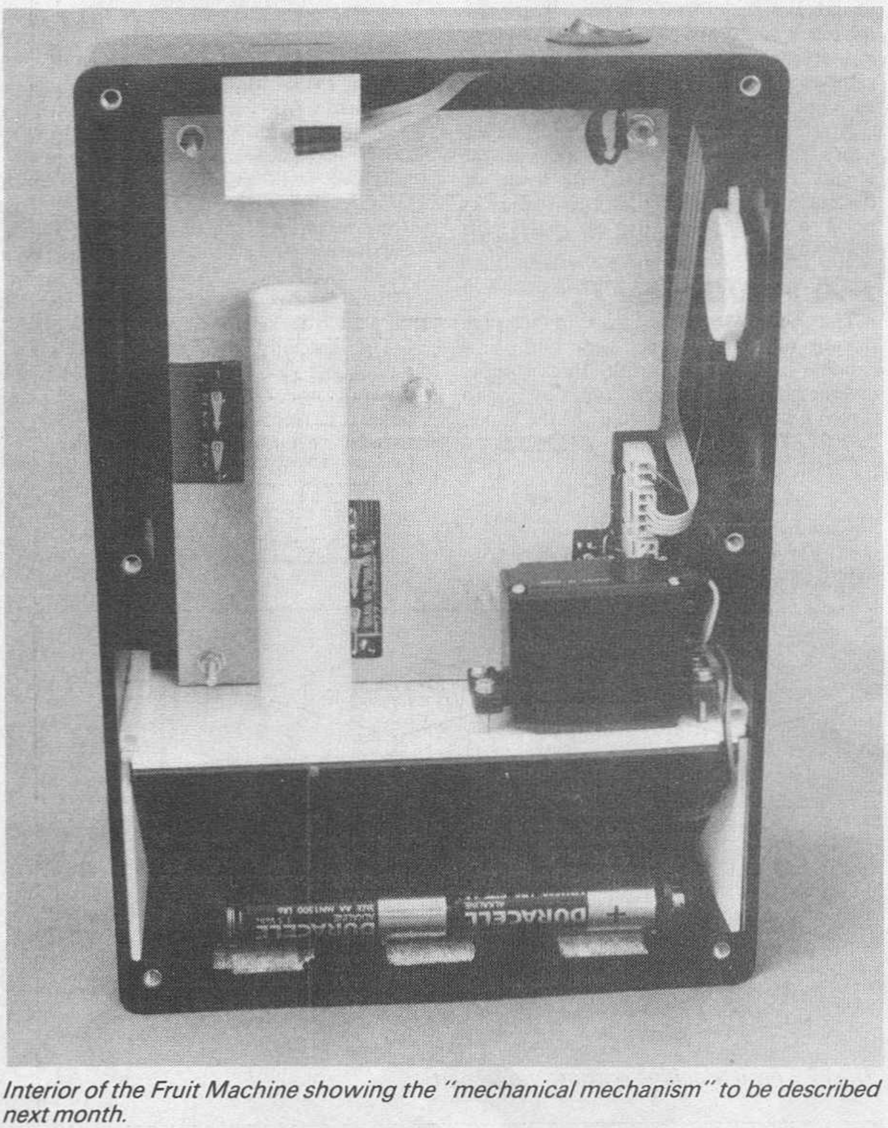
When all three reels have stopped, the winning line is analysed and the machine enters either the *win* mode, or returns to the *idle* mode if the game is lost. The *win* mode consists simply of a short sound and light sequence, after which the *payout* mode is entered. In the case of wins with three fruits the same, the *gamble* mode may be entered. Here, the win is either collected or gambled up or down. The *nudge* mode just steps all three reels forward or backward by one fruit.

In the *payout* mode, the "odds" table is read and a counter is set up to pay out the required number of coins. The servo motor is then moved to and fro and the counter decremented until it reaches zero. After payout, the Fruit Machine returns to the *idle* mode.

The random number generators, used to decide the winning line and to control the *hold* and *gamble* features, are simply fast counters which cycle continuously and are read each time the start button is pressed. It is impossible to anticipate the values of the counters, however, making it impossible to cheat!

IN A SPIN

A "mechanical analogy" of one of the Fruit Machine's reels is shown in Fig. 2. Although the system is essentially "all software", the algorithms of the *spin* mode were closely modelled on the equivalent mechanical system shown. The principles used are best described using this analogy, simply publishing parts of the source code would make very dull reading indeed!



Interior of the Fruit Machine showing the "mechanical mechanism" to be described next month.

The three reels each have six fruit symbols, but a total of 30 individual steps. This enables a reel to be displayed part way between two fruits for animation purposes, although the reel cannot stop in this position. Each reel has a speed parameter which is used to step the reel forward at a constant rate. Each time a reel is stepped, the piezo electric sounder output is toggled giving a "click" sound.

Initially, the reel is set spinning at a constant speed, then, after a short period, the speed parameter is decremented at a constant rate which slows the reel down. To ensure that the reel stops accurately on the fruit, rather than half way between two fruits, slowdown is delayed until the selected fruit passes through the win line. The complete slowdown process then takes exactly two revolutions until the speed parameter reaches zero and the reel stops.

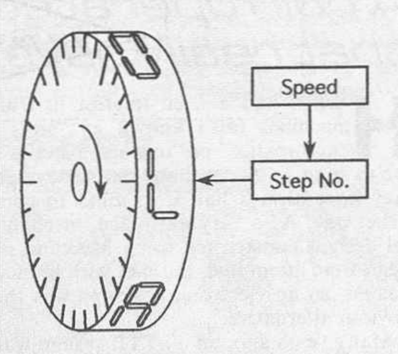


Fig. 2. Mechanical analogy.

MECHANICS

Since the Fruit Machine handles real coins, the job of getting them into and out of the machine requires a couple of mechanical devices.

Insertion of coins is handled by the coin detector mechanism. This uses a simple infra-red beam which is broken as the coin drops through. Whilst this design does not have any obvious security features, tampering is countered by measuring the time for which the beam is broken. Durations outside of a "window" value are rejected thereby ignoring the insertion of "inappropriate" objects.

Coins are payed out by the coin payout mechanism which uses a simple sliding tray to pull the coins, one at a time, from the bottom of the coin stack. It is driven by a servo motor, the type typically used in radio controlled models.

Both the coin detector mechanism and the coin payout mechanism are constructed, very simply, out of sheet plastic available from most model shops. A length of plastic pipe is required for the coin stack which is easily obtained in the form of overflow pipe for water tanks, available from builders merchants.

COMMERCIAL SCENE

The design of the Fruit Machine was, to a certain extent, inspired by the techniques used in commercial machines. For this reason, and by way of a small diversion, it may be interesting to take a look at the way these fascinating machines work.

Unlike early mechanical machines, which used electricity just to illuminate the front glass, modern machines are based entirely around complex microprocessor circuitry. The CPU board will typically contain a

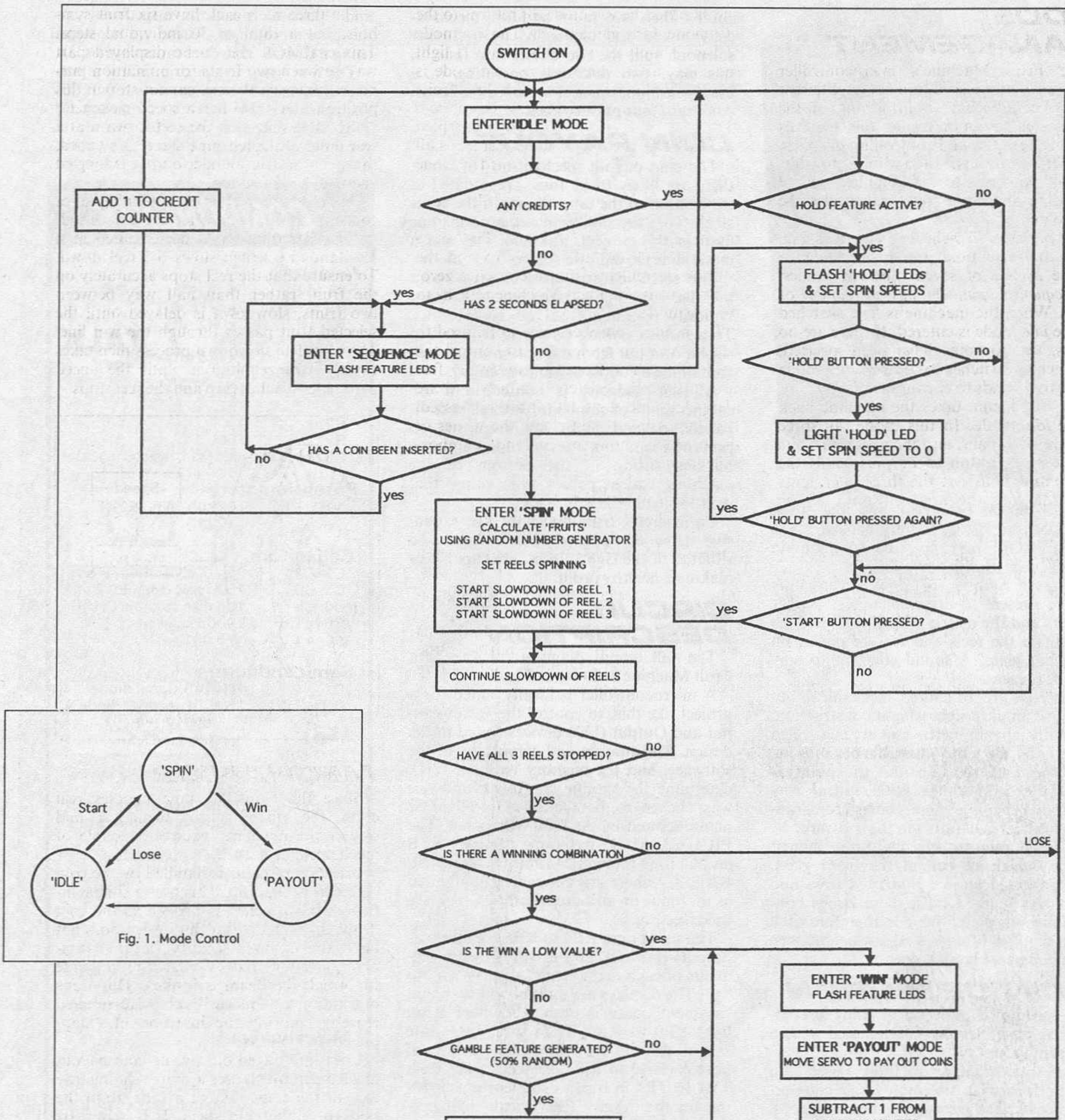


Fig. 1. Mode Control

Fig. 1. The EPE *Fruit Machine program flowchart*

Z80 or 68000 processor and the usual EPROM and RAM. Battery backed RAM or EEPROM may be used to maintain "odds" data during power off.

A large number of power transistors will be present to drive solenoids, stepper motors and the matrix of light bulbs which illuminate the reels and feature panels on the front glass. A sound effects chip may also be present.

The reels are, of course, mechanical, but being of an ultra light weight construction, have virtually no inertia and are controlled directly by the CPU using stepper motors. The speed of rotation and the point at which they stop is under CPU control. Any random behaviour here comes from random number generators in the software.

A large number of miniature filament lamps, which sit behind the front glass, are connected up in a matrix of rows and columns. Unlike l.e.d.s, these lamps conduct in both directions and therefore each lamp requires a series diode, which may be mounted in the lamp holder.

COIN DETECTION

Detecting the insertion of coins in commercial machines may be handled in two different ways.

The mechanical method uses an elaborate mechanism employing a counter-balanced cradle into which the coin drops, tipping the cradle over and sending the coin down a channel towards a microswitch which registers a credit.

Coins that are too small drop straight through the cradle and into the coin return chute, whereas large coins get stuck, requiring use of the coin reject lever. This forces open the whole mechanism allowing any large item to drop straight through. Additional safeguards include a magnet which attracts ferrous metal objects such as washers.

Modern coin detectors use a simple slide fitted with a number of coils through which a range of different coins can be passed. The coin changes the inductance of the coils as it passes, generating a unique signature for each coin.

Only coins with recognised signatures are accepted, a solenoid diverts alien devices to the reject chute. Once a valid coin has been detected, its signature is used to divert it down one of several different chutes.

A solenoid operated plastic paddle diverts the coin initially down one of two chutes, then two more paddles, mechanically linked and controlled by a further solenoid, split the two chutes into four. In this way, two solenoids operating in a binary fashion, can sort up to four different coins into four plastic tubes.

COIN PAYOUT

The coin payout mechanisms, of which there are likely to be four, are situated at the bottom of the tubes in which the coins stack. They are similar in design to the one used in this project, although they use a metal slide moved by a solenoid.

The solenoids are massive, each about the size of a mains transformer and are typically operated from 50 or 60 volts. Tremendous pulling power is required to slide a coin out from the bottom of a stack containing a couple of hundred coins.

All this gadgetry is housed in a tall cabinet made of chipboard with glass front panels. Several locks are employed to prevent access to a number of large plastic buckets sitting in the bottom of the machine which collect the coins that overflow from the coin stacks.

Commercial fruit machines are expensive items of equipment, although when situated in the right places, are capable of making a healthy profit.

CIRCUIT DESCRIPTION

The full circuit diagram for the *EPE* Fruit Machine is shown in Fig. 3.

A microcontroller is ideally suited for a project like this, to control the various Input and Output (I/O) devices found in the design. The amount and complexity of the software, and the memory required (2K), determine the specific controller, and this was chosen to be the 28-pin PIC16C57 manufactured by Arizona Microchip. The PIC16C57 (IC1) has three "ports" A, B and C, (one four-bit, A, and two eight-bit, B and C, where any bit can be configured as an input or an output) all of which are used (see Fig. 3).

The seven lines RB0 to RB6 are set up as outputs (port B), and drive the seven segments of each main "fruit" display, "a" to "g". The displays are multiplexed such that "segment" data is output via port B on lines RB0 to RB6. Then the appropriate "digit" drive bit on one of the four lines of port A (RA0 to RA3) switches transistors TR1 to TR4 in turn to sink current, lighting up the "digit" (the fourth digit corresponds to the "feature" l.e.d.s).

Segment drive "h" (RB7), which is usually the decimal point on 7-segment displays, is not connected as such, but is routed off to the l.e.d.s within the *hold* switches. Drive current to each of the segments is limited via resistors R1 to R8.

Each segment of the four displays is "overdriven" in turn by about four times its maximum rated current. This is acceptable and is done to increase the brightness of the displays. Because each segment is only on for a quarter of the time, there is no risk of damage to the displays or the drive transistors.

The clock circuit for IC1 uses a simple ceramic resonator for stability, and consists of components X4, C1 and C2. This generates a clock frequency of 1MHz.

The *start* and *hold* switches S1 to S4 "ground" the input lines RC4 to RC7 of port C (IC1) when pressed, and are otherwise pulled "high" by R32 to R36.

The servo requires two pulse trains of 1ms and 2ms at 50Hz for the "collect" and "payout" positions respectively, for the coin mechanism. These are generated using a CMOS 7556 dual timer chip (IC2).

The first timer in the chip (IC2a) is connected as an oscillator, generating the 50Hz via resistors R24, R25 and capacitor C3. This 50Hz output is connected to the trigger input of the second timer (IC2b), which

COMPONENTS

Resistors — See SHOP TALK Page

R1 to R8	56 (8 off)
R9 to R20	2k7 (12 off)
R21, R22	220 (2 off)
R23, R24, R28	4k7 (3 off)
R26, R29, R31	10k (3 off)
R30	15k
R25	100k
R27	150k
R32 to R36	4k7 (s.i.l. resistor pack)

Potentiometers

VR1, VR2	10k sub-min. preset (2 off)

Capacitors

C1, C2	22p disc ceramic (2 off)
C3, C9	100n disc ceramic (2 off)
C4, C5	10n disc ceramic (2 off)
C6 to C8	1000µ axial elect. 10V (3 off)

Semiconductors

D1	1N4148 signal diode
D2 to D5	1N4001 rectifier diode (4 off)
LED 5	min Infra red l.e.d.
LED 6 to LED 13	5mm l.e.d. std. (yellow) (8 off)
X1 to X3	0·8in. 7-segment display (common cathode) (3 off)
TR1 to TR5	BC548 *npn* silicon (5 off)
TR6 to TR13	BC558 *pnp* silicon (8 off)
TR14	min Infra red phototransistor
X4	1MHz ceramic resonator
IC1	PIC 16C57 (see text)
IC2	7556 dual CMOS timer

Miscellaneous

S1 to S4 (LED1 to LED4)	p.c.b. switch with internal l.e.d. (4 off)
S5	round rocker switch (black)
MO1	servo motor (Futaba FP.S14B)
PL1, PL2, PL4	p.c.b. 2-way plug (3 off)
PL5	p.c.b. 3-way plug
PL3	p.c.b. 4-way plug
SK1, SK2, SK4	p.c.b. 2-way skt (3 off)
SK5	p.c.b. 3-way skt
SK3	p.c.b. 4-way skt

28-pin i.c. socket; 14-pin i.c. socket; battery holder 4xAA (long type); battery clip (PP3 type); box ABS MB6; l.e.d. display filter (red); plastic sheet 0·060in. white; plastic sheet 0·080in. white; plastic sheet 0·080in. black; plastic tube 6mm diameter, 1 strip; plastic tube 21mm diameter, 100mm; plastic glue; paper clip; solder etc.; printed circuit board available from the *EPE P.C.B. Service,* code 914.

Approx cost guidance only **£65**

EPE MICROCONTROLLER FRUIT MACHINE – CIRCUIT DIAGRAM

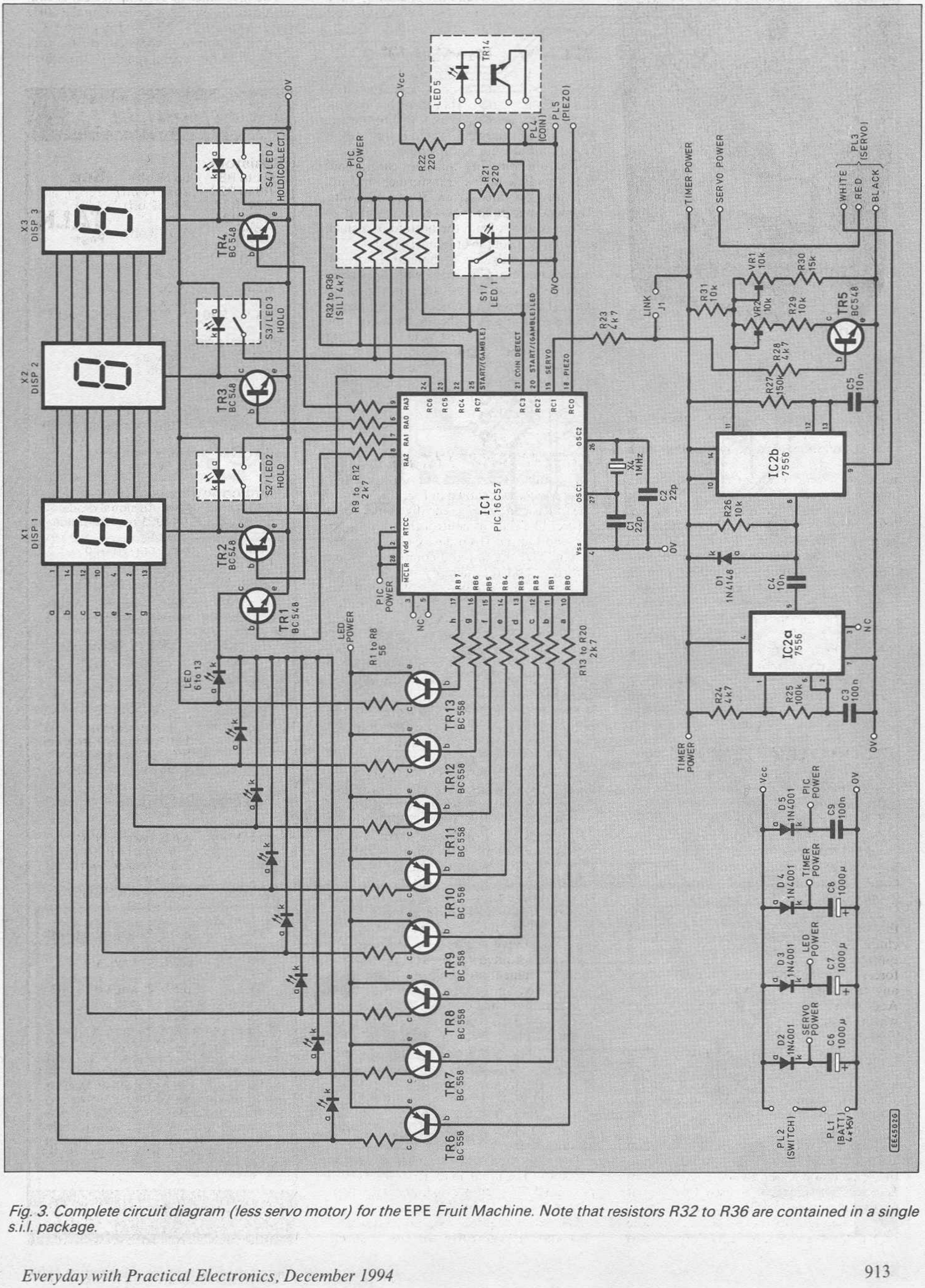
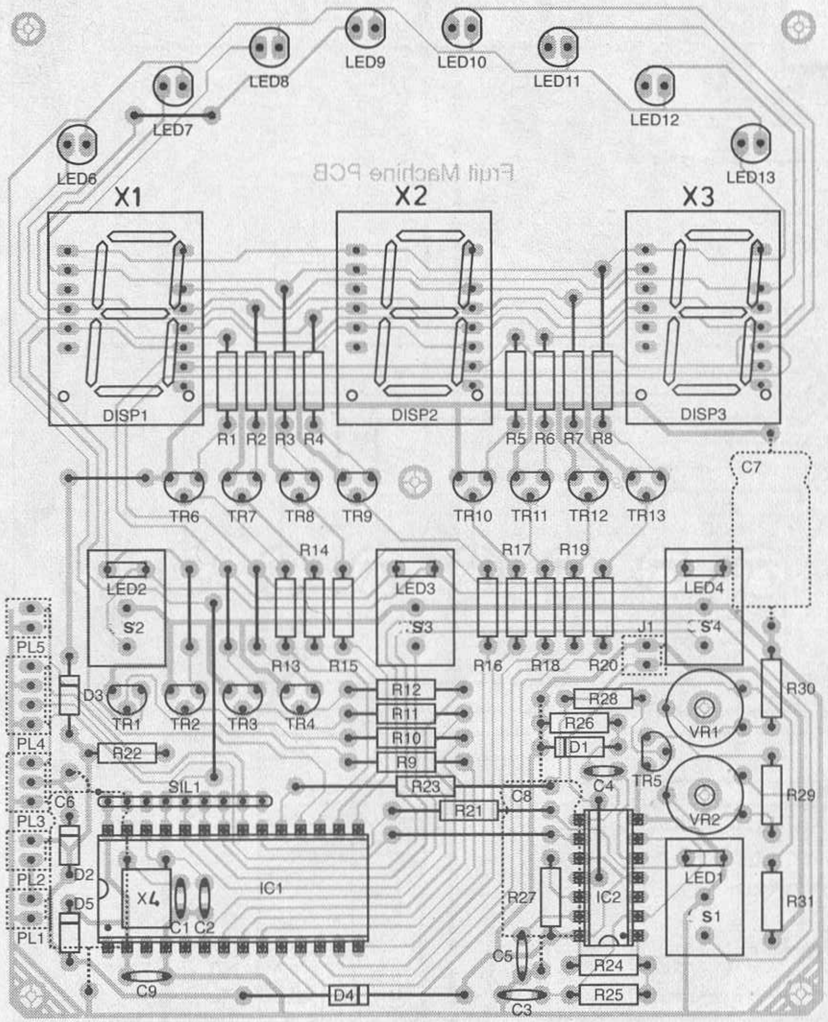


Fig. 3. Complete circuit diagram (less servo motor) for the EPE *Fruit Machine. Note that resistors R32 to R36 are contained in a single s.i.l. package.*



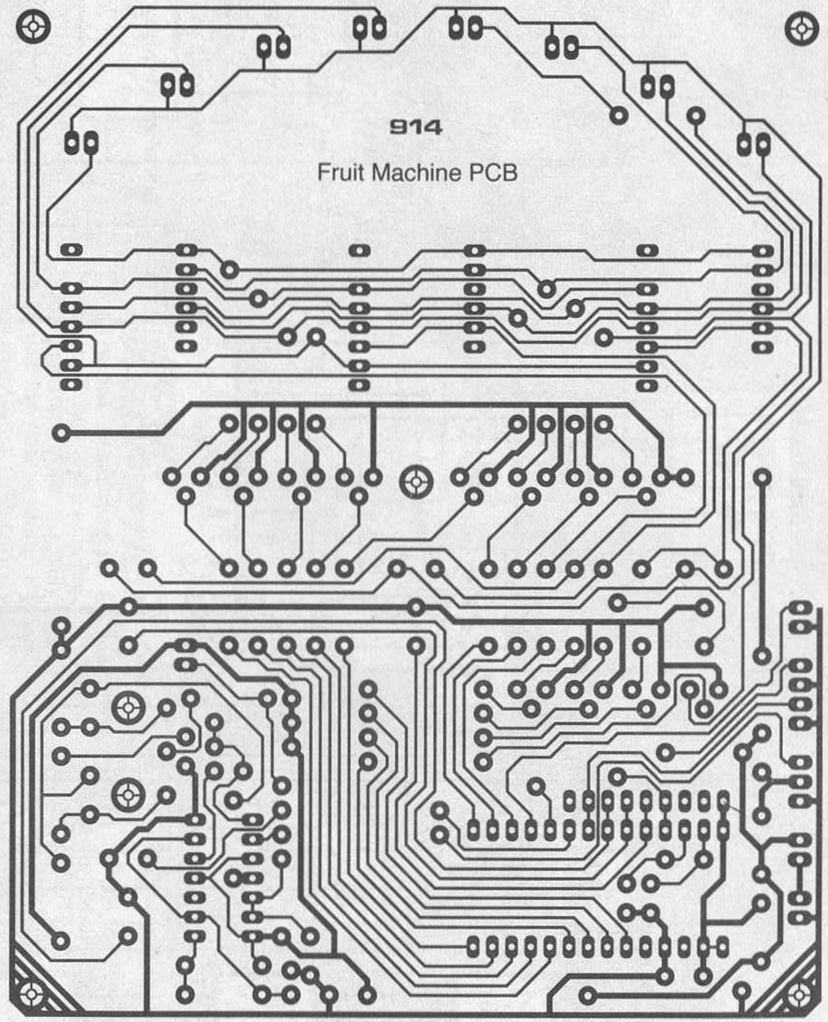
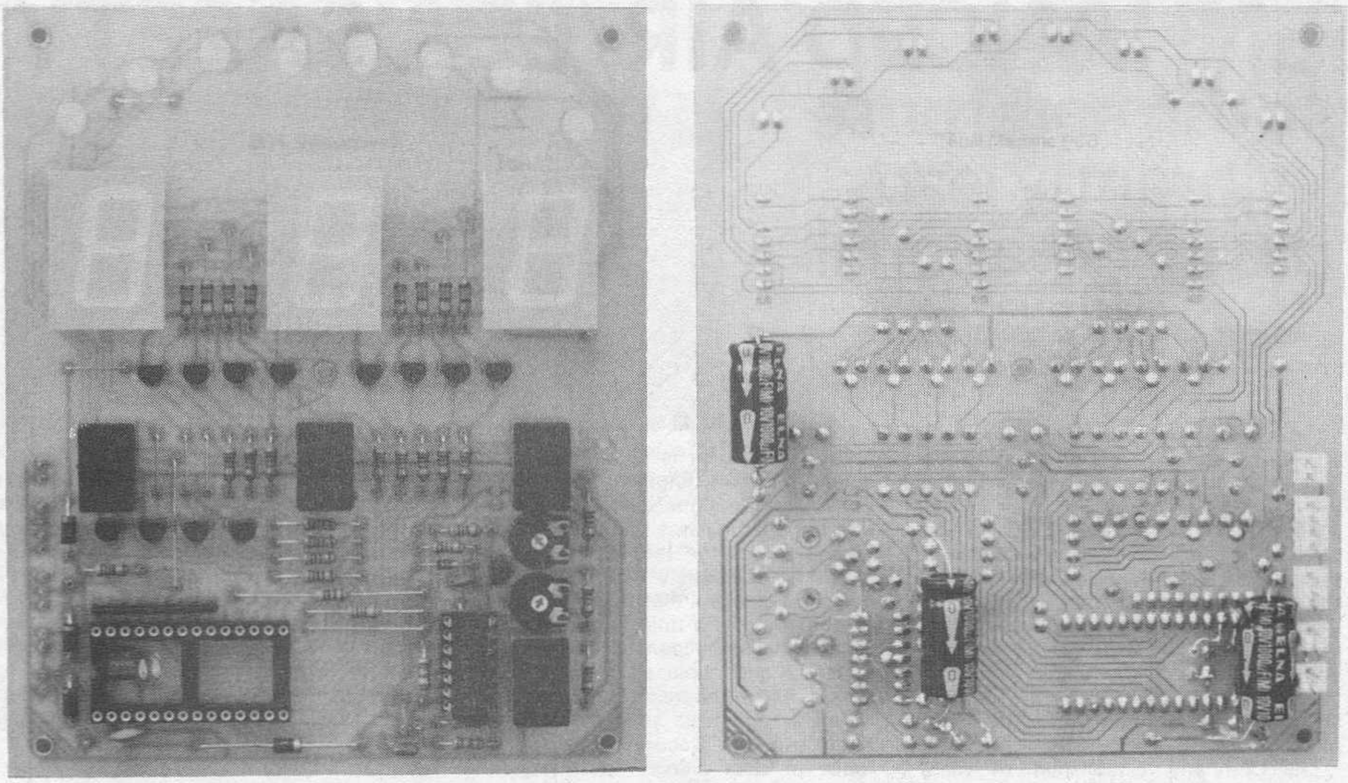


Fig. 4. Fruit Machine printed circuit board component layout and full size underside copper foil master pattern. This board is available from the EPE PCB Service, code 914.



Top and underside views of the completed p.c.b. Note the electrolytic capacitors and connectors on the underside.

is connected in monostable mode, giving the correct pulse width determined by resistor R27 and capacitor C5. The voltage at the reference pin (pin 11), is adjusted by preset VR1 to obtain the 2ms pulse. TR5 is switched on via link J1 to select a parallelled resistor pair which generates the 1ms pulse train, and this is adjusted using preset VR2 (see "Testing" – next month).

There are four isolated power supplies to power the l.e.d.s, servo, timer and microcontroller i.c.s. In each case, a diode "taps off" the battery supply (D2 to D5), isolating and localising any interference. Each supply is smoothed and decoupled with a capacitor (C6 to C9). The diode in the "PIC power" section (D5) reduces the maximum voltage for IC1 to a safer working level, as a new set of four batteries may exceed the 6V maximum supply rating for this i.c.

Sound is generated as a square wave, by toggling a bit (RC0) on IC1 at an appropriate frequency, (depending on the feature), and this signal is connected directly to the piezo electric sounder.

P.C.B. ASSEMBLY

The printed circuit board (p.c.b.) component layout and foil master pattern is shown in Fig. 4.

Due to the nature of construction, some of the components are not mounted flush on the p.c.b, notably the, *feature* l.e.d.s. As a rough guide, the legs of these eight yellow l.e.d.s should be cut to a length of 16mm, and then should be soldered as high off the p.c.b. as possible.

The eight *feature* l.e.d.s, the three *hold* switches and the *start* switch all protrude from the front panel of the box, thus the cut-outs need to be quite accurately made so that the p.c.b. will make a snug fit. The main displays have a red filter fitted in front of them. This increases the contrast of the displays, and it really works! It fits in one piece behind the cut-outs in the front panel of the box. Note that these cut-outs are actually smaller than the displays themselves.

Construction proceeds by first fitting the seven links, and all the resistors including the presets. Then fit the capacitors, diodes and transistors, displays and l.e.d.s. Finally fit the switches, but note that the green l.e.d. in the *start* switch needs to be turned around. This can be done quite easily by disassembling the switch housing with a small watchmakers screwdriver, and it is easier than it sounds!

Note that some components are fitted underneath the microcontroller chip (IC1). Next fit the sockets for the microcontroller, and the 7556 timer (IC2). Finally, fit the three 1000µ capacitors on the back of the p.c.b. and fit the i.c.s when required, during testing.

The connectors are also mounted on the reverse side of the p.c.b, and because the p.c.b. is single-sided, care should be taken when soldering the plug pins to it. It may be easier to push the pins of the connector until they protrude equally from either side of the plastic mounting, and then solder them to the p.c.b, pushing the plastic part of the connector flush to the p.c.b. last.

Next Month: Mechanical assembly and testing.