EDUCATED EMMA

ELECTRONIC MIME MOBILE ANIMAL

By G.C.BROWN
M.S.H.A.A. A.M.R.S.H.

This article is an extension of the EMMA project published in the March and April 1969 Practical Electronics. It is expected that readers wishing to add EMMA's new capability will be familiar with the previous articles; the component numbering is carried on from the earlier circuits and reference is made to diagrams in the March and April 1969 issues. We regret that we are no longer able to supply copies of these issues.

Since the formative weeks following EMMA's rather difficult birth back in March she has, as we would have expected, already come of age. Indeed, she now exhibits a kind of self-preservation awareness which encourages her to perform simple work tasks for a living. More accurately, given the right situation EMMA really "wants" to work because to do so is now part of her make-up and she can learn that quite often this will pay-off.

In order to embody this new faculty EMMA's shape has filled out just a little with an additional circuit board. However, the modifications to her existing systems are not unduly complicated and the keen Bionics constructor will probably be overjoyed to know that at last he can have a semi-intelligent "animal".

ANATOMICAL CHANGES

To encourage EMMA to work in return for reward requires a few extra circuit blocks and if the reader refers to Fig. 1, a clear impression of the technique will be gained.

The philosophy behind the original scheme for EMMA has not been changed drastically, but there are now included such items as a Schmitt trigger which monitors the supply voltage level and of course the inevitable learning circuit with which by now we must all be familiar. This embodies a pair of monostables, one (the extension monostable) having a duration of 20 seconds and the other (the differential monostable) a period of 1 second.

As usual there are also included an AND gate and a summer with its attendant learnt threshold Schmitt which triggers upon the summer level reaching some pre-determined value.

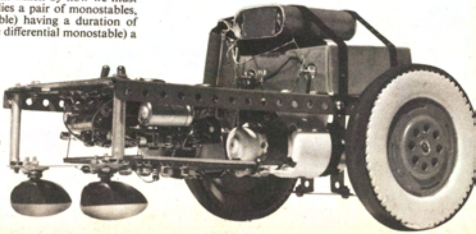
DESIGN PHILOSOPHY

Now it is intended that EMMA should learn to work, so this implies that she must additionally have a need to work in the first place. If a situation is made sufficiently attractive she will be prepared to do some simple chore provided she has a previous memory of being rewarded.

These requirements are largely accommodated by deliberately reducing EMMA's muscle control supply for short periods. This makes her hypersensitive to loads during which she is encouraged to carry a heavy book or similar object.

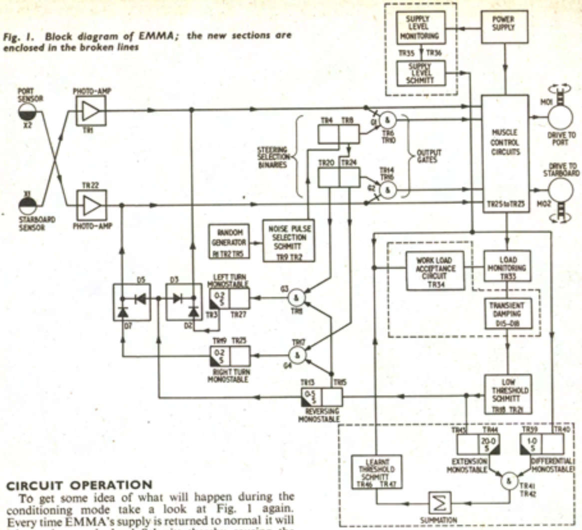
Periodically we may give her some "reward" by returning the supply to normal so that she realises that we intend to pay her when the work has been done.

We achieve all this in a somewhat synthetic way by switching out one of the cells forming part of the forward drive supply battery. Thus during conditioning her supply for the forward mode is a little less than 3 volts unless we provide a reward, in which case it rises to about 4·5V.



Complete "Educated EMMA", now with three circuit boards

Fig. 1. Block diagram of EMMA; the new sections are enclosed in the broken lines



CIRCUIT OPERATION

To get some idea of what will happen during the conditioning mode take a look at Fig. 1 again. Every time EMMA's supply is returned to normal it will trigger the supply level Schmitt thereby causing the differential monostable to fire.

Assuming just prior to this that a physical load has been applied then the load monitoring section will have previously fired the extension monostable. As a result, and provided the differential monostable fires during the time the extension monostable is in the quasi-stable condition, the AND gate will be enabled and consequently the summer output level will begin to rise.

If we repeat the process a number of times the existence of the reward can obviously become significant because the increasing level from the summer will ultimately reach a point where the learnt threshold Schmitt fires.

Immediately this occurs the work-load acceptance circuit will raise the threshold of the load monitoring system allowing EMMA to tolerate greater loads, indeed, the very same kind of loads she would accept were her supply to be at a normal level. However, she has at this stage learnt to understand that her supply will return to normal and so she "soldiers on" in the knowledge that all will be well.

Nevertheless, if we decide to stop rewarding EMMA her memory for the "good life" will gradually diminish as the summer level falls, until a point is reached where the load will no longer be tolerated. At such times she will "twist and turn", being thoroughly intractable as her normal reflexes take over and the avoidance system goes into operation.

Like any real creature EMMA, given the opportunity, can improve her chances for continued existence by taking advantage of certain situations. Thus she can adapt herself to doing a small task if it promises some form of payment and just as easily give the job up if not adequately reimbursed.

CIRCUIT IMPROVEMENTS AND MODIFICATIONS

In her existing form EMMA will normally function quite satisfactorily and so if it is not intended to add the new circuitry her "neurology" can be left as it is. Nevertheless, there are certain improvements that can be made and certain modifications that must be attended to before adding the learning system.

The changes are all extremely simple and so will be indicated in relation to the existing circuit diagrams for the reflex and muscle control sections discussed in the March and April issues of P.E. The relevant areas of discussion are in Figs. 2 and 5, in the March and April 1969 issues respectively.

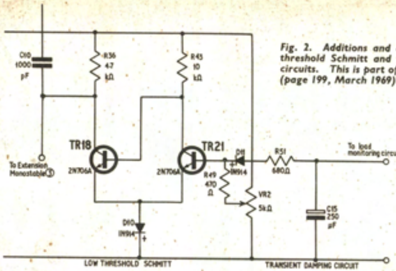


Fig. 2. Additions and alterations to low threshold Schmitt and transient damping circuits. This is part of the reflex circuits (page 199, March 1969)

TRANSIENT DAMPING CIRCUIT

In this circuit (Fig. 2, March 1969) a diode must be added (cathode end to base of TR21) in series with R51 to ensure that the voltage across C15 is entirely attributable to the output from the load monitoring system. Otherwise C15 can charge via VR2 and R49. Resistor R49 must be reduced to 470 ohms. Fig. 2 (above) shows the relevant section of the circuit.

LOW THRESHOLD SCHMITT

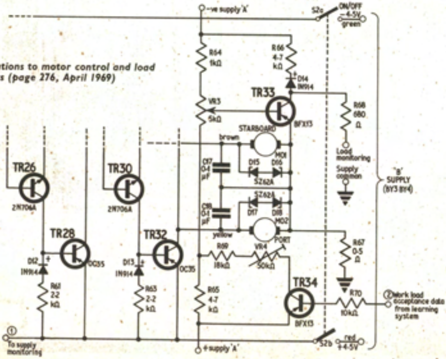
The resistor R40 must be removed and replaced with a diode (Fig. 2), its cathode being taken to the −4·5V rail of the "A" power supply. This modification results in there being an almost constant potential between TR18 and TR21 emitters and the negative rail. As a consequence the backlash of the Schmitt is effectively reduced to zero with the result that it comes on and goes off almost at the same point.

A connection from the low threshold circuit must also be taken from the collector of TR18; this can take the form of a short piece of insulated wire and may be coiled back out of the way until it is called upon to connect the reflex circuitry with the extension monostable discussed later.

MUSCLE CONTROL SYSTEM

In earlier articles we discussed the problem of motor noise; the "hash" was reduced using a pair of capacitors C17 and C18, across the motors (Fig. 5, April 1969). An improvement has now been embodied which really minimises the problem. This involves using a pair of 6V Zener diodes connected back-to-back (as shown in

Fig. 3. Alterations to motor control and load sensing circuits (page 276, April 1969)



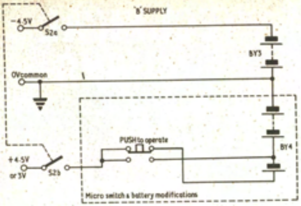


Fig. 4. Circuit diagram of the new "B" power supply and switch wiring

Fig. 3) across each motor. Noise spikes of either polarity and in excess of the Zener voltage of one diode and the forward voltage drop of the other are thus suppressed.

Additional diodes (D12 and D13) are connected in series with R61 and R63 (cathodes to the bases of TR28 and TR32 respectively) and also D14 in series with R66 (anode to collector of TR33). These are included to prevent any paths between the supply being monitored (the "forward" half of this supply) and the supply which feeds the monitoring circuit ("A" supply).

For similar reasons the load monitoring circuit is now not run from the "A" supply and suitable arrangements must be made to reconnect R64 and R66 to the negative rail of the "A" supply. The resistor R65 must go to the positive rail of the "A" supply and is shunted with the series combination R69, VR4, and TR34 (Fig. 3) which constitutes the work load acceptance circuit.

"B" POWER SUPPLY

The forward-mode battery (type 126) of the "B" supply requires a small modification so that either 3V or 4·5V may be obtained. This entails carefully opening the paper flap at the top of the battery with a razor blade and taking a connection from the 3V tapping (i.e. one cell down from the positive side of the battery). The 4·5V and 3V outputs thus obtained are then taken to a double pole changeover microswitch (Fig. 4) so that in use EMMA's forward operation can be obtained from either normal or reduced supplies.

This completes the various modifications to the existing hardware and we are now in a position to concentrate on the learning system, also to the way in which it interconnects with the rest of EMMA's person (see Fig. 5).

SUPPLY LEVEL MONITORING

This circuit comprises a Schmitt trigger which is similar in form to the type mentioned earlier (i.e. it has extremely little backlash) and has its input connected via R71 to VR5 which goes to the positive rail of the "B" supply. Adjustment of VR5 sets the threshold at which the Schmitt fires; generally this need only be just at the "B" supply level and no lower.

The capacitor between TR35 base and the negative rail of the "A" supply prevents transients switching the Schmitt.

Once set-up the Schmitt trigger will switch whenever the voltage at the positive rail of the "B" supply falls below normal (influenced by operation of the micro-switch). Hence TR35 will turn off and TR36 will come on with the result that TR37 will cease to conduct. With TR37 collector positive TR34 will turn off and consequently EMMA will be extra sensitive to loads.

When the supply is returned to normal TR35 will again turn on and TR36 will turn off. At this time the positive voltage at TR36 collector will be passed to the differential monostable causing it to fire. Simultaneously, TR37 will turn on again thereby raising the load threshold.

DIFFERENTIAL AND EXTENSION MONOSTABLES

Both monostables are a little unconventional in that they each use extra transistors forming the Darlington pairs TR38, TR39 and TR44, TR45. These provide higher gain and hence permit larger timing resistors to be used.

Diodes D22 and D23 provide a fair degree of noise immunity and so prevent the monostables from triggering prematurely if any short-term voltage drop occurs on the "A" supply. Under such conditions D22 and D23 are reverse biased and the associated capacitor (C21 or C22) effectively bridges the interval during a voltage drop "holding-up" the collector of the transistor that is turned off.

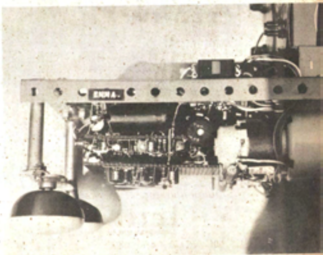
The extension monostable is triggered from the load threshold Schmitt and fires whenever the load exceeds a certain level. As mentioned earlier the differential monostable triggers whenever the positive end of the "B" supply is returned to normal.

COINCIDENCE GATE

The coincidence (AND) gate comprises TR41 and TR42. Assuming a sufficiently heavy load has been applied to EMMA then the extension monostable will have fired hence turning off TR42.

If during the 20 second period of the extension monostable the positive rail of the "B" supply has been returned from low to normal then the differential monostable will be triggered.

View of "Educated EMMA" showing the position of the new circuit board



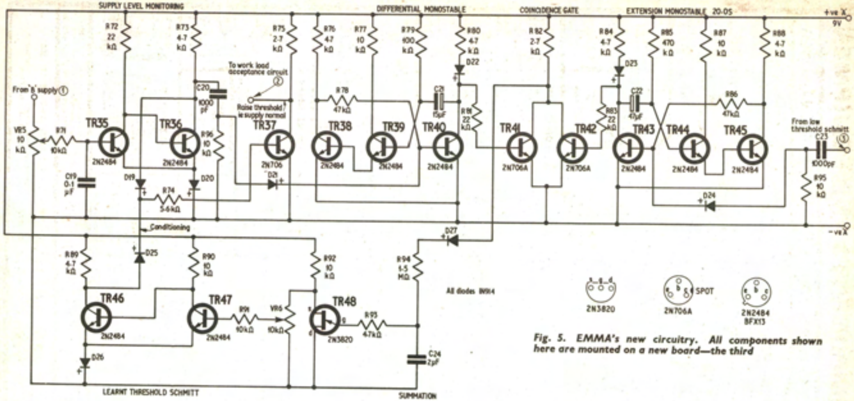


Fig. 5. EMMA's new circuitry. All components shown here are mounted on a new board—the third

COMPONENTS . . .

Resistors

R49	470Ω	R78	47kΩ	R88	4·7kΩ
R69	18kΩ	R79	100kΩ	R89	4·7kΩ
R70	10kΩ	R80	4·7kΩ	R90	10kΩ
R71	10kΩ	R81	22kΩ	R91	10kΩ
R72	22kΩ	R82	2·7kΩ	R92	10kΩ
R73	4·7kΩ	R83	22kΩ	R93	4·7kΩ
R74	5·6kΩ	R84	4·7kΩ	R94	1·5MΩ
R75	2·7kΩ	R85	470kΩ	R95	10kΩ
R76	4·7kΩ	R86	47kΩ	R96	10kΩ
R77	10kΩ	R87	10kΩ		

Potentiometers

VR4 50kΩ
VR5 10kΩ
VR6 10kΩ
} skeleton preset

Capacitors

C19 0·1μF
C20 1,000pF
C21 15μF elect. 12V
C22 47μF elect. 12V
C23 1,000pF
C24 2μF non polarised 63V

Diodes

D10 to 14 IN914 (5 off)
D15 to 18 SZ62A or equivalent 6V Zener (4 off)
D19 to 27 IN914 (9 off)

Transistors

TR34 BFX13
TR35, 36 2N2484 (2 off)
TR37 2N706A
TR38–40 2N2484 (3 off)
TR41, 42 2N706A (2 off)
TR43–47 2N2484 (5 off)
TR48 2N3820

Miscellaneous

D.P.S.T. microswitch
Veroboard 5in × 2½in, 0·1in matrix

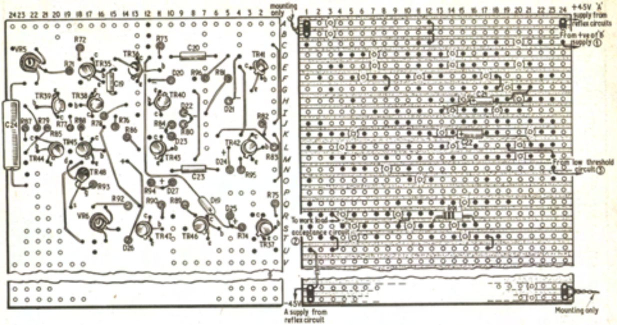


Fig. 6. Component layout and wiring for the new board: (a) component side, (b) copper side showing breaks in the copper strips

Transistor TR41 will also turn off, and the common collector point of TR41, TR42 will go positive for a time, essentially determined by the period of the differential monostable, i.e. one second or less if the extension monostable is close to the end of its quasi stable state. The output from the coincidence gate is taken to the summation circuit.

SUMMATION CIRCUIT AND "LEARNT" THRESHOLD

As implied by its designation, the summation circuit adds or integrates the output pulses from the coincidence gate and comprises TR48 and its associated components. Capacitor C24 and R94 provide a time-constant sufficiently long to ensure that the maximum summation limit extends to accepting greater than 15 input pulses.

Unwanted discharge of the capacitor is minimised by inclusion of D27 and by the very high input impedance presented by TR48 which is an f.e.t. Initially TR48 will be conducting, but as pulses from the coincidence gate gradually charge C24 so the voltage at TR48 source will climb towards the positive rail.

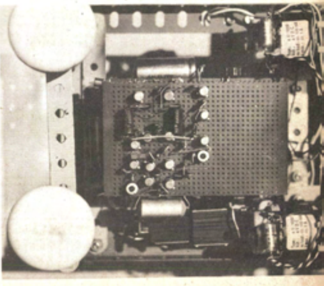
At some level of summation, dependent upon where VR6 has been set, the learnt threshold Schmitt will switch causing TR37 to turn on. This condition will remain until the level on C24 drops below the point necessary to maintain the Schmitt in the triggered state.

However, due to the reasons discussed earlier this will take a fair time and consequently TR37 will remain on to ensure that EMMA accepts higher loads at low supply levels. Of course, if this state of affairs is not reinforced periodically by giving EMMA a short rise in her "B" supply level then the voltage across C24 will gradually decay to a point where the load threshold drops again.

CIRCUIT BOARD CONSTRUCTION

The method for layout and wiring of the learning system circuit board is shown in Figs. 6a and 6b. Depending on the potentiometers used the Veroboard may require some drilling, however, all other components are mounted by way of their individual leads. The board itself is attached to the existing reflex board by 18 s.w.g. wire soldered to its four corners.

Underside view of EMMA showing the new circuit board



It is important to note that all necessary breaks in the copper strip should be made prior to mounting the various components. Care should be taken to ensure that the complete width of the copper has been removed at each break.

Always mount transistors and diodes last and be sure not to keep them in contact with the soldering iron longer than necessary.

CHECKOUT

When the work on the circuit board has been completed it should be carefully examined to make sure that no dry joints or solder bridge-overs exist and that all components are carefully connected. It can now be inter-connected with the remainder of EMMA's anatomy.

Set EMMA's muscle control and the reflex system switches on. Connect a meter between the zero point of the supply batteries and the positive rail of the "B" supply to ensure that the level is approximately 4·5V. Operate the microswitch and check that this level falls to 3V. Release the microswitch and disconnect the meter. Inhibit EMMA's random generator circuit by turning the associated Schmitt permanently on through the use of VR1. Ensure that both motors are running.

SUPPLY LEVEL SCHMITT

Place EMMA on the ground and adjust VR2 so that she will carry a relatively heavy load, but goes into the avoidance reaction upon bumping into an obstacle.

Return EMMA to the work bench and with the meter connected between the collector of TR36 and the negative rail of the "A" supply, adjust VR5 until the supply level Schmitt *just* triggers, evidenced by the meter reading almost rail potential. Operate the microswitch and ensure that the meter reading drops to near zero level; if not, re-adjust the Schmitt. Disconnect the meter.

Now place EMMA back on the ground and replace the load. Ensure that, as before, the avoidance reaction does not occur unless she meets with an obstruction. Operate the microswitch and check that both EMMA's speed is reduced and that she immediately goes into the avoidance mode. If she is functioning correctly return EMMA once more to the table.

DIFFERENTIAL AND EXTENSION MONOSTABLE

Connect the meter between the common collector point of TR41, TR42 and the negative rail of the "A" supply; there should be an almost zero reading.

Now simulate a load by stalling the road wheels and, shortly following this, operate the microswitch. There should be a reading of almost rail potential. If not, check that the differential and extension monostables are functioning—the meter connected to either TR40 or TR43 collector will establish this following triggering.

Transfer the meter to the source of TR48. Momentarily short out C24 when the meter reading should be approximately 1V. Trigger the extension monostable, as before, and operate the microswitch every couple of seconds or so. Ensure that there is a gradual increase in the meter reading.

Note that it may be necessary to re-trigger the extension monostable because its time period could have elapsed during this check. Momentarily short out C24 again and check that the meter reading falls once more to about 1V.

LEARNT THRESHOLD SCHMITT

Connect the meter now to the collector of TR46 and set VR6 wiper about midway. The reading on the meter should be near zero. Operate the microswitch occasionally and apply a simulated load from time to time. Ultimately the meter will indicate that the learnt threshold Schmitt has triggered.

Naturally, it is a matter of choice as to the point in the summation curve where one wants this Schmitt to trigger, but a sensible arrangement would be to have the summer integrate about ten or eleven pulses before this occurs. It is simple to control this factor by varying the setting of VR6.

FINAL CHECK

If everything checks out remove the meter and short out C24 again to make sure EMMA forgets all about our unbridled inquisition of her internal parts. Set EMMA down on the floor once more and make this final check!

Place a fairly heavy book on EMMA's back and operate the microswitch periodically. After a time (that will probably seem like an eternity) EMMA will carry the load under reduced power supply conditions. The easiest way to maintain the low supply state for a while is to clip a clothes peg across the microswitch and so hold the operating button depressed.

Remember that EMMA's batteries don't last forever, so do start off with fresh ones. A heavily loaded supply on its "last legs" may make it virtually impossible to set up the monitoring circuits for reliable operation.

FINAL EMMA

You may have every reason to say "All this just to have a heap of electronics and metalwork behave in this odd fashion." But that is the very point, it *is* just a heap of electronics and metalwork—not a living creature! Crude though she may be EMMA definitely shows certain preferences and can learn that some actions are worth the trouble while others are not.

To demonstrate that a machine can have a kind of self preservation awareness, we have cheated a little by playing around with the power supplies used. The reason though is valid because had we employed, say, re-chargeable nickel cadmium cells it would have been virtually impossible to see EMMA exhibit this new ability.

However, there is no reason why a keen Bionics man should not attempt an even more ambitious scheme—after all there is a machine in existence which can go and plug itself into the nearest 13 amp socket when it feels peckish! ★