# VELA

# USER AND TECHNICAL MANUAL

VELA Laboratory Manual 1.0

## INTRODUCTION

This manual gives the user of VELA all the instructions needed to operate the instrument. Because VELA is able to perform so many functions and has many sophisticated features, there are, of necessity, many instructions, and this manual should be read carefully in order to be able to use the instrument most effectively.

The first part of this manual contains general descriptions and operating instructions; the second part explains in detail each of the functions that VELA can perform.

Because VELA is a new concept in laboratory instrumentation, this manual is very detailed in order to give as much guidance as possible. Much of the material is repeated where it is relevant and therefore most of the information for a particular use is in one place.

## DESCRIPTION OF VELA

VELA is microprocessor based and is capable of performing the function of many different items of conventional equipment, such as scalers, timers, frequency meters and storage oscilloscopes. To use VELA, it it not necessary to be able to program a microprocessor. All the programs, or routines, that are likely to be required are stored in a ROM (read only memory) and can be called by the user by typing in a two digit number using the keypad on the front of the instrument. It is however, possible for the user to write a program for the machine if the stored programs are inadequate for the user's particular requirement.

VELA is able to monitor voltages on four input channels, and monitor pulses on a separate pulse input channel. The inputs can be in the range +/-250 mV to +/-25 V.

The measurements made by VELA can be displayed on an oscilloscope, a chart recorder or on the integral 8-digit display according to the wish of the user and the particular program being used. Data can also be transferred to a microcomputer so that, for example, calculations can be performed on the data.

A diagram of the controls and connectors on the outside of the instrument, and a schematic block diagram of the circuit inside the instrument, appear on the following two pages. The description which follows should be read in conjunction with these diagrams.

## 1 ANALOGUE INPUTS

Data which comes in the form of a variable voltage (eg from temperature sensors, pH meters, measurements in electric circuits) is put into VELA via these inputs. The input sockets are on the left hand side of VELA. The 4 mm sockets will take BNC adapters.

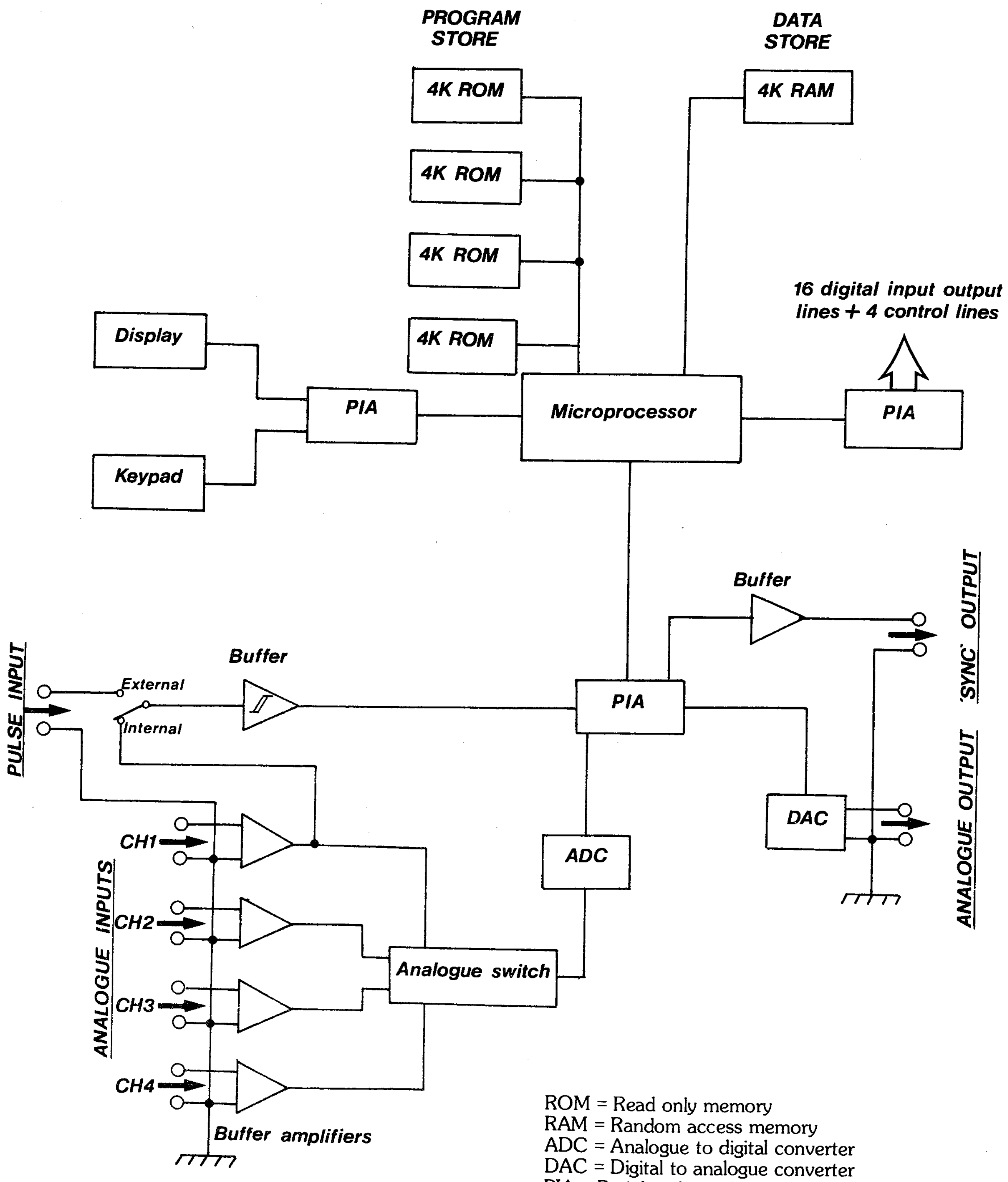
It can be seen from the diagram that each of the four analogue inputs is connected to an amplifer. This amplifier provides three input ranges: +/-25 V, +/-2.5 V and +/-250 mV. The desired range is selected by a switch, which is on the top panel of VELA, on the left hand side, level with the appropriate input socket.

No harm will be done to the instrument if the input exceeds the maximum voltage on any range, so long as a maximum of +/- 40 V is not exceeded.

An input outside the range +/-40 V is liable to damage the input buffer chip. This is cheap and easy to replace, however, and thus effectively acts as the input fuse.

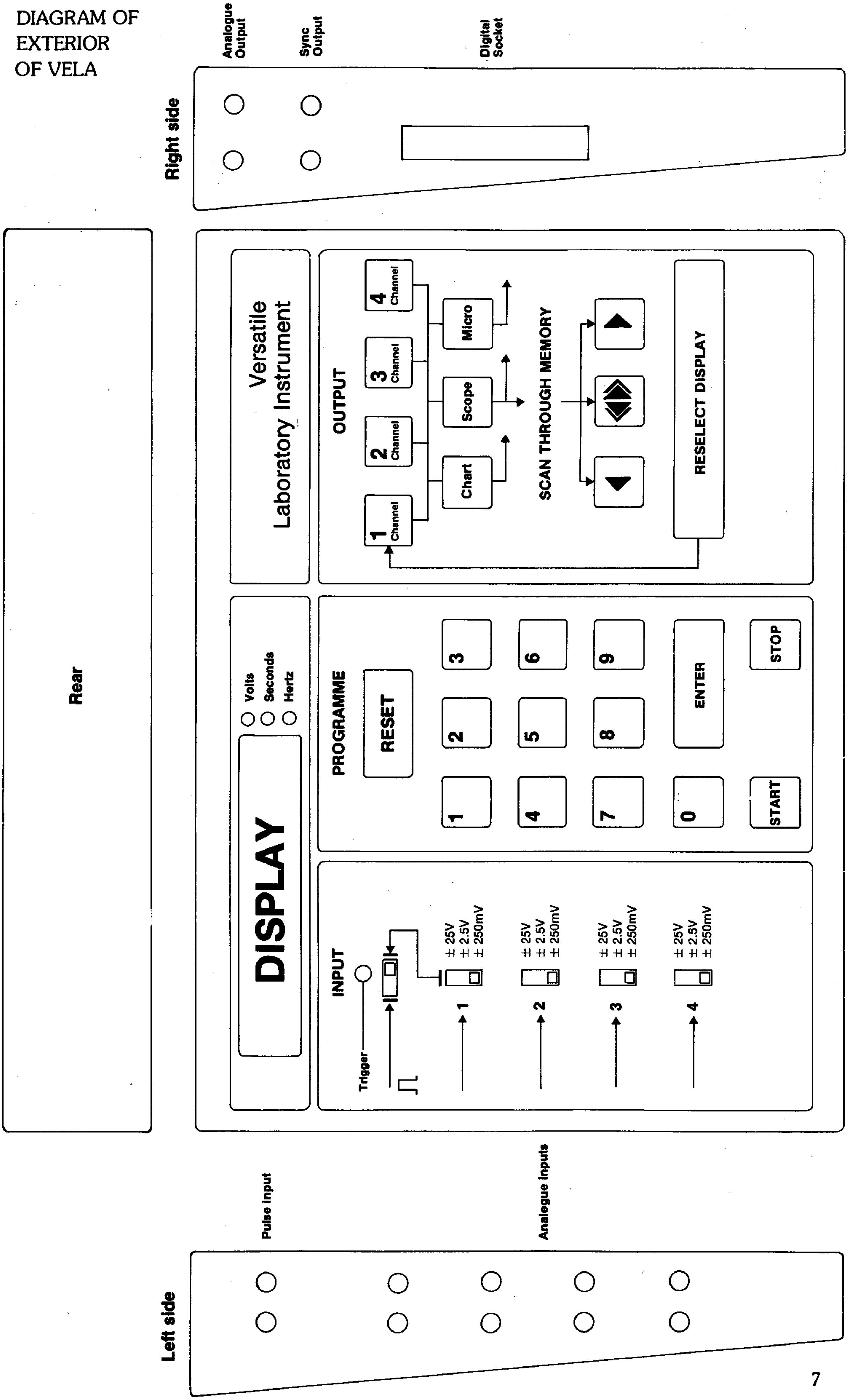
The input impedance of each analogue channel is approximately 1 Megohm.

BLOCK DIAGRAM OF INSIDE OF VELA




ROM = Read only memory
RAM = Random access memory
ADC = Analogue to digital converter
DAC = Digital to analogue converter
PIA = Peripheral interface adaptor

DIAGRAM OF
EXTERIOR
OF VELA

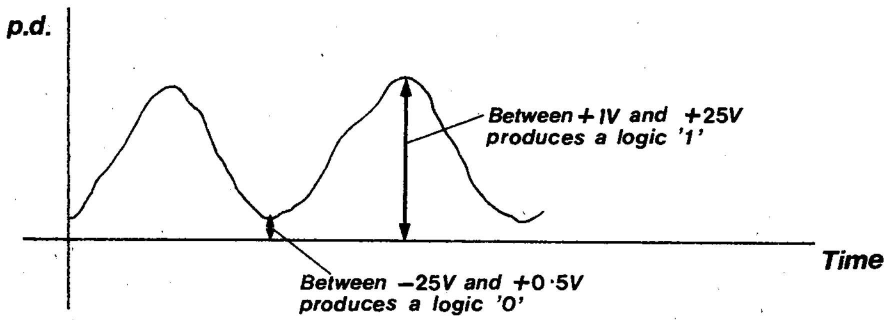


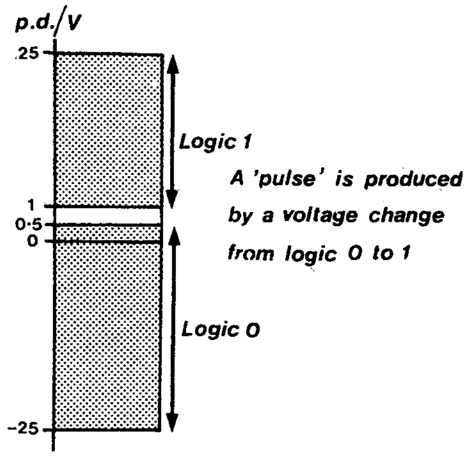
## 2 PULSE INPUT

In some applications, data, which comes in the form of pulses or alternating waveforms, must be supplied to the instrument via the pulse input terminals, which are also on the left of the instrument next to the analogue inputs. Examples of such data include pulses from a radioactivity detection apparatus, timing pulses when using VELA as a timer, and pulses which synchronise data logging with the event being monitored.

The pulse input is connected to a pulse shaping circuit (see diagram on page) which changes state, or triggers, when the input exceeds approximately 1.0 V. Thus input pulses or waveforms of any shape can be connected to the pulse input providing the "peak" voltage is greater than 1.0 V and the 'trough' voltage is less than approximately 0.5 V, as shown in the diagram below. In other words, the pulse shaping circuit introduces hysteresis so that 'clean', unambiguous pulse detection occurs even with relatively slowly changing signals which may have a certain amount of noise superimposed on them. An example of this would be the signals from a light gate that is interrupted fairly slowly.

Note that the pulse input does not detect a zero crossing of the signal—merely a change from below approximately +0.5 V to above approximately +1 V (ie suitable for TTL level signals).




The voltage limits are +/-25 V.

The light emitting diode (LED) on the top panel next to the input terminals will be illuminated when the pulse input is high, ie greater than 1.0 V.

The input impedance of this circuit is approximately 1 M ohm.

In some applications it is useful to be able to amplify a small amplitude input waveform (eg from a microphone) before the signal is fed to the pulse shaping circuit. The output from the channel 1 amplifier can be connected to the pulse input by means of the slider switch at the top left hand side of the front panel, underneath the LED. To use this facility, the pulses should be connected to channel 1. The channel 1 amplifer should be switched to a suitable range. The pulse input slider switch should be switched to the right hand side linking it with the channel 1 input.

When using this facility, switching will occur much closer to a zero crossing condition, the switch thresholds now being approximately 100 mV and 50 mV respectively.

## 3 KEYPAD

This is touch sensitive and occupies most of the top surface of the instrument. It is used for supplying instructions, to the instrument, as described in Operating Instructions, section 1.2.

## 4 DISPLAY

The upper left hand corner of the top panel contains VELA's 8-digit display. This is used, for example, to display the program number that has been requested and to display values of stored data. There are also 3 light emitting diodes in the display; these are used to indicate the appropriate units that accompany the numbers displayed (volts, seconds or hertz).

## 5 ANALOGUE OUTPUT

The analogue output socket is used to connecte VELA to an oscilloscope or chart recorder. This socket is situated on the right hand side of the instrument.

## 6 'SYNC' OUTPUT

This socket is on the right hand side of the instrument. It is for connecting to the 'external sync' socket found on most oscilloscopes. Use of this facility gives better trace stability with some oscilloscopes. See Section 1.3, Oscilloscope Instructions, for further details.

This output socket is also used with some programs for providing a voltage pulse for starting an experiment under the control of VELA. Full details are given in the instructions for the relevant programs.

## 7 26-WAY DIGITAL SOCKET

This is on the right hand side of the instrument. To this socket are connected 16 digital input/output lines, together with 4 control lines (see schematic diagram on page ). This socket is used:

a) for transfer of data to and from a microcomputer.
b) for monitoring up to eight 2-state sensors simultaneously (using for example the multiple timer program, no 06).
c) in connection with providing outputs of sequential codes for control applications.

Note that VELA has not got overload protection on these lines. They are designed to accept or give out TTL compatible signals. An add-on buffer board is available, which contains protection circuits as well as 2 mm screw sockets to make connection to the digital lines easier. The use of this board is strongly recommended when connecting VELA to any control set up which uses these lines.

Suitable cables can be supplied to enable VELA to be connected to most popular microcomputers (contact the manufacturers for details).

The pin connections to this socket are as follows:

| | | | |
|---|---|---|---|
| 1 | Earth | 14 | PB0 |
| 2 | Earth | 15 | PA7 |
| 3 | +5 V | 16 | PA6 |
| 4 | Earth | 17 | PA5 |
| 5 | Control input/output (CB2) | 18 | PA4 |
| 6 | Control input (CB1) | 19 | PA3 |
| 7 | PB7 | 20 | PA2 |
| 8 | PB6 | 21 | PA1 |
| 9 | PB5 | 22 | Control input/output (CA2) |
| 10 | PB4 | 23 | PA0 |
| 11 | PB3 | 24 | Control input (CA1) |
| 12 | PB2 | 25 | Earth |
| 13 | PB1 | 26 | Control input (CA1) (ADDRESS $C002) |

## 8 POWER SUPPLY

The power supply socket is at the rear of the instrument. A mains (240 V) power supply is included. VELA needs an 8 to 12 V dc or ac power supply. It draws a maximum current of 0.5 ampere.

VELA can be used with an 8 to 12 V battery outside the laboratory. The size of the battery depends, of course, on the length of time for which VELA will be operated; for example, a 6 hour run requires a battery capaciy of 3 ampere-hours - easily provided by relatively small rechargeable cells. For longer time periods, lightweight plastic motorcycle batteries are often satisfactory.

Where necessary, the current can be reduced further to approximately 0.3 A by replacing the PIA integrated circuits with lower power CMOS varieties. (Contact the manufacturers for details.)

## 9 BATTERY BACK UP OF MEMORY

VELA is equipped with an on board battery to provide data retention on power down. Data memory is provided by low standby power CMOS integrated circuits.

If VELA has not been used for a considerable period of time then it should be left connected to a power supply for several days to ensure that the pcb battery is adequately recharged before use in the field.

Data that is stored in memory after power down can be retrieved when power is reapplied by making use of program 15 and transferring the contents of VELA's memory direct to a microcomputer. Thus VELA can gather data in the field and later transfer it to a microcomputer for further analysis.

An increase in data retention time can be obtained by using 6116 CMOS RAM ICs in place of the existing memory ICs (6116 ICs have even lower standby power requirements).

## OPERATING INSTRUCTIONS

These operating instructions must be read in conjunction with the instructions for the individual programs.

1 Connect VELA to a suitable power supply. This should be 8 to 12 V ac or dc. VELA draws a current of 0.5 A. A specially designed mains powered unit is supplied.
2 Connect the input sockets (ie the analogue and pulse inputs) on the left hand side of VELA to the equipment, or sensors, as appropriate.
3 Connect the output sockets on the right hand side to an oscilloscope, or other equipment, if required.
4 The keypad has been arranged as logically as possible. The left hand side is used to give instructions to VELA about which program is required, when to start and stop, etc. The right hand side is used to recover data stored in VELA, for example, after a data logging program.
5 Switch on the power. The word 'HELLO' will appear on the display for a few seconds, after which a 'P' will appear on the left hand side of the display. If something else is displayed (eg VELA has already been used for another program), press 'RESET'.
6 Type the two-digit number of the program you wish to use on the keypad. Notice that all programs have two digits, so 'leading zeros' must be included for program numbers less than 10. (eg for program number 4, type '04'). The program number you type will appear at the left hand side of the display.
7 Many programs then require a 'parameter' to be typed in, for example to define the time between readings of the input voltage. This can be a one, two or three digit number. Type the required parameter on the keypad: this parameter will appear at the right hand side of the display as it is typed. Parameter details can be found in the particular program description in Chapter 2.
8 Check that the display is correct. If it is, press 'ENTER'; if not press 'RESET' and start again. Note that if the program requested does not exist in any of the ROMs in VELA, the instrument will probably 'crash'. If this happens, press 'RESET'; if a 'P' does not appear on the display, switch off the power and start again.
9 Those programs concerned with data logging and timing require a 'start' instruction. This can be provided by pressing 'START', or in many cases by providing a pulse to the pulse input socket. This is explained more fully in the appropriate instructions for the individual programs.
10 Most programs can be stopped by pressing 'STOP'.

## FOR DATA LOGGING PROGRAMS

The right hand side of the keypad is used mainly to recover data stored during a data logging program.

11 Data logging can be finished by pressing 'STOP' (except on program 01). Data logging will stop automatically when the VELA memory is full. The fact that data logging has finished is indicated by a flashing '0-P' on the display.
12 After logging is complete, press 'CH 1', 'CH 2', 'CH 3' or 'CH 4' according to which channel was used to log the data. The chosen channel number will appear on the left hand side of VELA's display. If ANY other key (except 'RESET') is pressed, VELA will default to channel 1.
13 Press 'SCOPE', 'CHART' or 'MICRO' according to whether the data is to be read out on an oscilloscope, a chart recorder or transferred to a microcomputer. It is necessary to correctly set up the relevant piece of equipment to receive the data before pressing one of these keys.
14 Data is sent to an oscilloscope repetitively; while data is being sent to an oscilloscope, the chosen channel number is shown on the left of the VELA display, and the value of the first item of data logged on that channel appears on the right of the display. To stop data output to an oscilloscope press 'RESELECT DISPLAY'; a flashing '0-P' will appear on the display; return to instruction 12.

For Programs 01 and 03 only (medium and slow speed transient recorders). If channel 1 is selected, only data stored in that channel is sent to the oscilloscope. If channel 2, 3 or 4 is selected, data stored in the selected channel is sent alternately with data from channel 1. If the oscilloscope is correctly adjusted with a timebase speed of 2 milliseconds/div or greater and an appropriate trigger level setting, the oscilloscope will behave as a dual beam oscilloscope so that data stored in channel 1 can be compared with data stored in any other channel.
15 Data is sent to a chart recorder or microcomputer only once; after data transfer is complete, the display will show a flashing '0-P'; return to instruction 12.

16 Data can be shown one item at a time on VELA's display as follows:

a) Choose the channel number as in 12 above. The number of the selected channel will be shown on the left of the display.
b) Press 'SCOPE' as in 13 above, even if there is no oscilloscope connected. The chosen channel number will appear on the left of the display, a '1' (for 'first item') will appear in the middle of the display, and the value of the first item of data logged on the chosen channel will appear on the right of the display as described in 14 above.
c) Press ' > '; the chosen channel number will flash momentarily on the left of the display, the 'item number' (2) will appear in the middle of the display, and the second item of data will be shown on the right. Press ' > ' again and the third item of data will be shown, and so on.
d) If the ' <<>> ' key is pressed at the same time as the ' > ' key, VELA will move forward by 16 items of data; this can be repeated by further simultaneous pressing of the 'FAST' and 'FWD' keys.
e) To move backwards through the data, use the ' < ' key instead of the ' > ' key.
f) A bright up cursor is displayed on the oscilloscope corresponding to the position of the data currently on VELA's display.

17 To change the data channel, or to change the instrument onto which the data is transferred (eg from oscilloscope to chart recorder), press 'RESELECT DISPLAY' and then start again at instruction 12.

**18 IN THE EVENT OF PROBLEMS:**

VELA should indicate 'HELLO' when switched on. If this does not occur then please check:

a) that the power supply being used is capable of delivering 0.5 A at a minimum of 8 V ac or dc.
b) that the fuse on the rear panel of VELA has not blown. If this needs replacing, a fast blow 1 A fuse should be used.

If VELA fails to operate as expected or does not respond in a predictable manner to instructions typed in from the keypad it is suggested that you check the following:

a) Look at the waveform of the power supply to VELA with an oscilloscope to check that it is satisfactory. Some power supplies incorporate thyristor switching and are unsatisfactory as the very brief switching transients can interfere with microcprocessor circuitry.
b) Check that transients on the mains (easily caused by plugging or unplugging items of equipment into the mains near the VELA power supply) are not causing the programs in VELA to 'crash'.

VELA, like most other microprocessor based pieces of equipment, is sensitive to spikes on the mains and whilst this is unlikely to cause any permanent damage, it will lead to apparant operating malfunctions. If this is the case, turn off the power supply to VELA, power up again, re-enter the program and proceed as before.

## OSCILLOSCOPE INSTRUCTIONS

## USING AN OSCILLOSCOPE TO DISPLAY THE DATA

With the data logging programs it is possible to connect an oscilloscope to the analogue output on VELA to provide a means of displaying the captured data. The data is often available on the analogue output line as it is read from the experiment, so that an oscilloscope can build up a picture of the data as it is logged. This occurs, for example, with program 03. Otherwise the data is available on the analogue output line after all the logging is complete.

The following notes are to help you obtain a steady, clear trace on your oscilloscope as quickly as possible. It is assumed that you have a basic knowledge of how to operate the oscilloscope you are using.

### CONNECTIONS TO OSCILLOSCOPE:

VELA is provided with an analogue output socket on the right hand side, for connecting to an oscilloscope. If trouble is experienced with picking up mains hum on the oscilloscope, check that the connecting leads are routed well away from any mains cables. If necessary, use a coaxial connecting lead.

### Y-SENSITIVITY:

The output from VELA has maximum values of +/-2.5 V. If there are 10 divisions in the y-direction on your oscilloscope screen, (as is typical), then a sensitivity of 0.5 V/divison will be found to be suitable for virtually all applications.

### TIMEBASE SPEED:

It takes about 0.05 milliseconds to output each item of data to the oscilloscope. The timebase that you use depends on how much data you wish to display on the oscilloscope. For example, the slow speed transient recorder can collect a maximum of 1023 readings per channel, and it will take just over 50 milliseconds to output them all to an oscilloscope. To display all these readings will require a timebase speed of 5 milliseconds/division (assuming the x-axis is divided into 10 divisions).

If fewer readings are required to be displayed then a faster timebase speed can be used, eg a timebase speed of 1 milliseconds/division will display approximately the first 200 readings.

If in doubt (eg you are not sure how many relevant readings you have stored) it is suggested you start with a timebase speed of 5 milliseconds/division, and then adjust it as necessary.

Notice that you have to start reading from the first item of data. You cannot, for example, just display the last 100 items of data.

### TRIGGER LEVEL:

This is the key control for a stable oscilloscope trace.

NB Some simple oscilloscopes do not have a trigger level control, in which case this section is irrelevant However, it may be difficult to obtain a stable trace on such oscilloscopes.

Oscilloscopes have an electronic arrangement to make the trace on the screen start when the input voltage at the Y-input reaches a preset level. This is done so that an oscilloscope can always start its trace at the same point on an incoming signal, thus ensuring a stable trace. The trigger control can usually be set to 'automatic', in which case the trace will start when the input voltage is zero (eg midway beetween the positive and negative peaks of an ac waveform).

For use with VELA, the oscilloscope needs to start its trace at the start of the data (which will not usually be zero!). So that the oscilloscope 'knows' where the start of the data is, VELA gives out a short +2.5 V pulse just before it starts sending out the data. If the trigger level control is set to 2.5 V, then the oscilloscope trace will start as soon as that pulse arrives, and hence you will have a stable trace.

In practice the trigger level control is not calibrated, so you have to find the right setting of the control by trial and error. The important thing is that the control should NOT be on its 'automatic' setting; you must set the trigger level yourself.

VELA works well with a wide variety of oscilloscopes. However, if you are unable to obtain a stable trace on your oscilloscope, this could well be the result of a malfunction of your oscilloscope rather than a fault on VELA. The triggering facility on many old oscilloscopes is particularly poor.

## EXTERNAL SYNC:

Even with the above internal trigger control working properly, it is still sometimes difficult to obtain a stable trace. This particularly occurs if the output signal to the oscilloscope rises to near +2.5 V, when the oscilloscope can become confused between the output signal and the trigger pulse.

To overcome this problem, many oscilloscopes are provided with an 'external sync' socket (sometimes labelled 'External Trigger'). The oscilloscope trace will trigger when a pulse arrives at this socket, provided the appropriate control on the oscilloscope has been switched to 'external sync'.

There is an 'external sync' socket on the right hand side of VELA. A pulse is given out from this socket at the same time as the trigger pulse on the output signal. To use this facility, connect a lead from the 'external sync' socket on VELA to the 'external sync' socket on the oscilloscope, and switch the appropriate sync control on the oscilloscope to 'external'.

If you still have problems with triggering you could try reducing the level of the sync signal coming from VELA with a simple two resistor potential divider network and feeding this reduced signal into the external trigger socket of your oscilloscope.

## CHART RECORDER INSTRUCTIONS

Output of data to a chart recorder

With most of the data logging programs it is possible to connect a chart recorder to VELA to provide a 'hard copy' of the data stored in VELA. The chart recorder should be connected to the analogue output on the right hand side of VELA (the same output that is used for an oscilloscope).

### Y-SENSITIVITY:

The maximum output range from VELA is +/-2.5 V. The y-sensitivity of the chart recorder should be set so that full scale deflection is obtained with a voltage greater or equal to +/-2.5 V. Notice that the chart recorder pen must be set to the middle of the paper if the chart recorder is to respond to negative values of voltage.

### TIMEBASE SPEED:

Data is transferred to the chart recorder at the rate of 1023 items in approximately 5 minutes. A timebase speed of 10 cm/minute will be found suitable in nearly all cases. The time axis can be calibrated if the rate at which data was originally collected is known.

### PROCEDURE:

Connect the chart recorder to VELA and switch it on. Data transfer to the chart recorder is started by selecting a data channel and then pressing 'CHART' on the right hand side of the keypad; see the individual program instructions for further details. Switch on the chart recorder motor BEFORE pressing 'CHART'.

VELA sends data to the chart recorder in the reverse order to that in which it was collected, ie last item first, so that the resulting graph is the 'right way round'. After it has sent all the data, VELA will draw a y-axis on the chart. Disconnect the chart recorder after this has occurred, then press 'RESELECT DISPLAY' on the VELA keypad.

### NOTE

It takes about 5 minutes to output all the data stored in one channel to a chart recorder. This slow speed enables the majority of chart recorders found in laboratories to respond to the fine detail in the captured waveforms.

SUMMARY OF AVAILABLE PROGRAMS

| Program Number | Parameter | |
|---|---|---|
| 00 | Four channel digital voltmeter | 1 to 4 (channel number) |
| 01 | Fast transient recorder (single channel) | 0 to 999 (x50 microseconds) |
| 02 | Analogue (transient) recorder | 1 to 999 (milliseconds) |
| 03 | Analogue (transient) recorder, slow | 1 to 999 (seconds) |
| 04 | Frequency meter | |
| 05 | Event timer | 1 to 4 (pulse type) |
| 06 | Multichannel timer | |
| 07 | Pulse counter | 1 to 999 (seconds) |
| 08 | Statistics of interpulse times | 1 to 999 (x10 milliseconds) |
| 09 | Statistics of random events | 1 to 999 (seconds) |
| 10 | Versatile waveform generator | 0 to 999 (milliseconds) |
| 11 | Control sequence generator | 1 to 999 (seconds) |
| 12 | Ramp generator | |
| 15 | Transfer of data, from VELA to microcomputer | |
| 16 | User program creation | |

## FOUR CHANNEL DIGITAL VOLTMETER

| | |
|---|---|
| Description: | This program measures the voltages at the four analogue inputs and shows the value of one of these voltages on the display. Not only can this program enable the logger to be used as a straightforward voltmeter, but, with suitable sensors, it can be used for a wide variety of other measurements, eg temperature, pH, etc. |
| Program number: | 00 |
| Input: | Any dc voltage in range +/-25 V to each of the four analogue inputs. |
| To use this program: | 1 Connect the experiment, sensors, etc to the analogue inputs as appropriate;<br>2 select the appropriate input voltage range using the three position slider switches;<br>3 press 'RESET';<br>4 press '00' to select this program;<br>5 press 'ENTER';<br>6 the right hand side of the display will now show the input voltage (in volts) of channel 1. The display is updated every half second.<br>7 To change the channel which is being read, press 'CH1', 'CH 2', 'CH 3' or 'CH 4' as appropriate. The left hand side of the display shows the channel which is being monitored.<br>8 If the input is too high for the range selected, the display flashed 'HI'. If it is too low it flashes 'LO'. |

## FAST TRANSIENT RECORDER

Description: This program records the voltage at the 'channel 1' analogue input as a function of time. The sample rate can be 34 microseconds, or multiples of 50 microseconds up to 999 x 50 microseconds.

Program number: 01

Parameters: 0 to 999. This defines the time. A parameter of 0 will give 34 microseconds between readings. A parameter between 1 and 999 gives 50 microseconds multiplied by that parameter. For example, a parameter of 1 instructs VELA to take readings every 50 microseconds; a parameter of 2 instructs VELA to take readings every 100 microseconds; and so on.

Input: To channel 1. The input must be in the range +/-25 V.
A pulse might also be required on the pulse input to start data logging. (See below).

Maximum data: 4092 readings.

To use this program:
1 Make appropriate connections to the channel 1 input;
2 select the appropriate input range using slider switch (+/-25 V, +/-2.5 V or +/-250 mV);
3 press 'RESET';
4 press '01' to select this program;
5 use the keypad to type in the parameter, ie to define the time between readings as explained above;
6 press 'ENTER'; the parameter will disappear from the display;
7 to actually start recording data,
EITHER a) press 'START' OR
b) apply a positive pulse (greater than 1 V) to the pulse input. This enables the data collection to be synchronised with the event being monitored.

The display will go blank until logging is complete.
When 'START' is pressed, the 'sync' output on the right of VELA goes from low to high (about 4 V), and stays high for the duration of the data logging. This high output can be used to start an experiment running, and provides an alternative means of synchronising the data logging with the experiment.
To stop logging. Logging will stop automatically after 4096 items of data have been recorded. The 'STOP' keypad will have no effect in this program.

Logging finished: The centre of the display shows a flashing 'O-P' when data logging is finished.

Output: The output instructions are given to VELA using the right hand half of the keypad.
The data is stored in memory in four blocks of 1023 readings.

Readings 1 to 1023 are in block 1,
1025 to 2047 are in block 2,
2049 to 3071 are in block 3,
3073 to 4096 are in block 4.
(Readings 1024, 1048 and 3072 do not exist!)
NOTE: The last 7 bytes of block 4 do not contain data but program parameters.

In any of the output methods described below, only ONE block of data can be handled at a time.

1 On an oscilloscope
a) Connect an oscilloscope to the output socket on the right hand side of VELA;
b) press 'CH 1', 'CH 2', 'CH 3' or 'CH 4' to select the block of data which is to be displayed on the oscilloscope. The display will show the chosen block number on the left;
c) press 'SCOPE'; the value of the first item of data in the chosen block will appear on the right;
d) adjust the oscilloscope as necessary - see section 1.3;
e) to stop the output to an oscilloscope press 'RESELECT DISPLAY'. '0-P' will appear on the display again. Another data block or display instrument can now be chosen.

2 On a chart recorder
a) Connect a chart recorder to the output socket on the right of VELA;
b) adjust the chart recorder to appropriate speed and sensitivity (see section 1.4); switch the chart recorder on;
c) press 'CH 1', 'CH 2', 'CH 3' or 'CH 4' to select the block of data which is to be transferred to the chart recorder;
d) press 'CHART'; data will be transferred to the chart recorder.

The display will show which item is being transferred and its value;

e) when data transfer is finished, switch the chart recorder off. VELA's display will show '0-P'. Another data block or display instrument can now be chosen.

3 One reading at a time on the VELA display

a) Press 'CH 1', 'CH 2', 'CH 3' or 'CH 4' to select the block of data which is to be displayed. The number of the chosen channel will appear on the left of the display.
b) Press 'SCOPE' (even if there is no oscilloscope connected); the value of the first item in the chosen block will appear on the right of the display, and a '1' (first item) in the middle of the display;
c) Press ' > '; the channel number will flash momentarily on the left, the second item of data in that channel will be shown on the right, and a '2' ('second item') will appear in the middle. Press ' > ' again and the third item of data will be shown, and so on;
d) If the ' <<>> ' key is pressed at the same time as the ' > ' key, VELA will move forward by 16 items of data; this can be repeated by further simultaneous pressings of the ' <<>> ' and ' > ' key;
e) If an oscilloscope is connected, a small 'cursor' will move along the oscilloscope trace, marking on the trace which item of data is being displayed;
f) To move backwards through the data, use the ' < ' key instead of the ' > ' key.
g) When finished, press 'RESELECT DISPLAY'. The VELA display will show '0-P', and another channel of data or output instrument can be chosen.

4 Transfering data to a microcomputer
It is necessary to program the microcomputer to receive the data. See the Technical Manual.
a) Connect the microcomputer to the digital socket on the right hand side of VELA;
b) Load and run the appropriate microcomputer program;
c) Press 'CH 1', 'CH 2', etc according to which block of data is to be transferred (see above);
d) Press 'MICRO';
e) when data transfer is complete, the VELA display will show '0-P' and a new data block or output instrument can be chosen.

## ANALOGUE (TRANSIENT) RECORDER

| | |
|---|---|
| Description: | This program records the voltage at all four input channels simultaneously as a function of time. The time between readings is defined by a parameter typed in by the user. |
| Program number: | 02 |
| Parameter: | 1 to 999. This defines the time in milli-seconds between each reading of the input. |
| Input: | On any combination of the four channels. The input to each channel must be in the range +/-25 V. |
| Maximum data: | 1023 readings per channel. |
| To use this program: | 1 Make appropriate connections to the inputs of VELA;<br>2 select the appropriate input voltage range to each channel using the slider switches;<br>3 press 'RESET'<br>4 press '02' to select this program;<br>5 using the keypad, type in the time (in milli-seconds) between readings (the 'parameter');<br>6 press 'ENTER'; the 'parameter' disappears from the display;<br>7 to actually start recording data, EITHER a) press 'START', OR:<br>b) apply a positive pulse (greater than 1 V) to the pulse input. This enables logging to be synchronised with the event being monitored.<br>8 to show that logging is taking place the 'seconds' light on the display will flash on and off. The rest of the display will be blank.<br>When 'START' is pressed, the 'sync' output on the right hand side of VELA goes from low to high (about 4 volts), and stays high for the duration of the data logging. This high output can be used to start an experiment running, and provides an alternative means of synchronising the data logging with the experiment being monitored. |
| To stop logging data: | press 'STOP'. (Logging will stop automatically after 1023 items of data per channel have been recorded.) |
| Logging finished: | This is indicated by '0-P' on the display. |
| Output: | the output instructions are given to VELA using the right half of the keypad. |

1 On an oscilloscope
a) Connect an oscilloscope to the output socket on the right hand side of VELA;
b) press 'CH 1',to display the channel 1 data, 'CH 2' to display the channel 2 data, and so on; the display will show the chosen block number on the left;
c) press 'SCOPE'; data stored in channel 1 will be displayed on the oscilloscope alternately with data stored in the chosen channel, thus giving a "dual beam" facility enabling the channel 1 data to be compared with data on any other channel. The oscilloscope timebase speed must be at least 2 milliseconds per division for this to work properly and the tigger level set to an appropriate position. If channel 1 is chosen, then only the data in channel 1 is sent to the oscilloscope;
d) adjust the oscilloscope as necessary - see section 1.3;
e) to stop output to an oscilloscope press 'RESELECT DISPLAY'. '0-P' will appear on the display again. Another data block or display instrument can now be chosen.
f) while data is being sent to the oscilloscope, the right hand side of the VELA display shows the value of the first item of data logged on the chosen channel, ready for stepping through the data one item at a time (see below).

2 On a chart recorder
a) Connect a chart recorder to the output socket on the right of the instrument;
b) Adjust the chart recorder to the appropriate speed and sensitivity (see section 1.4); switch the chart recorder on;
c) press 'CH 1' to print out the data from channel 1, 'CH 2' to print out the data from channel 2, and so on;
d) Press 'CHART'; data will be transferred to the chart recorder. The display will show which item is being transferred and its value;
e) When data transfer is finished, switch the chart recorder off. The VELA display will show '0-P'. Another data block or display instrument can now be chosen.

3 One reading at a time on the VELA display
a) Press 'RESELECT DISPLAY';
b) Press 'CH 1', 'CH 2', 'CH 3' or 'CH 4' to select the block of data which is to be displayed. The number of the chosen channel will appear on the left of the display.
c) press 'SCOPE' (even if there is no oscilloscope connected); the chosen channel number will remain on the left of the display and the value of the first item in that channel will appear on the right of the display, and a '1' (first item) in the middle of the display;
d) press ' > '; the channel number will flash momentarily on the left, the second item of data in that channel will be shown on the right, and a '2' ('second item') will appear in the middle. Press ' > ' again and the third item of data will be shown, and so on;
e) If the ' <<>> ' key is pressed at the same time as the ' > ' key, VELA will move forward by 16 items of data; this can be repeated by further simultaneous presses of the ' <<>> ' and ' > ' key;
f) if an oscilloscope is connected, a small 'cursor' will move along the oscilloscope trace, marking on the trace which item of data is being displayed;
g) to move backwards through the data, use the ' < ' key instead of the ' > ' key.
h) when finished, press 'RESELECT DISPLAY'. The VELA display will show '0-P', and another channel of data or output instrument can be chosen.

4 Transfer of data to a microcomputer
It is necessary to program the microcomputer to receive the data. See the Technical Manual.
a) Connect the microcomputer to the digital socket on the right of VELA;
b) load and run the appropriate microcomputer program;
c) press 'CH 1', 'CH 2', etc according to which block of data is to be transferred (see above);
d) press 'MICRO';
e) when data transfer is complete, the VELA display will show '0-P' and a new data block or output instrument can be chosen.

## ANALOGUE (TRANSIENT) RECORDER (SLOW)

Description: This program functions in the same way as program 02 (section 2.2.1) and records the voltage at all four input channels simultaneously as a function of time. The time between readings is defined by a parameter typed in by the user, and is in the range 1 to 999 s.

Program number: 03

Parameters: 1 to 999. This defines the time in seconds between each reading of the input.

Input: To any combination of the four channels. The input to each channel must be in the range +/-25 V.

Maximum data: 1023 readings per channel.

To use this program:
1 Make appropriate connections to the inputs of VELA;
2 select the appropriate input range to each channel using the slider switches;
3 press 'RESET';
4 press '03' to select the program number;
5 using the keypad, type in the time (in seconds) between readings (the 'parameter');
6 press 'ENTER'; the parameter disappears from the display;
7 to actually start recording data,
EITHER a) press 'START' OR:
b) apply a positive pulse to the pulse input.
This enables logging to be synchronised with the event being monitored.
When 'START' is pressed, the 'sync' output on the right hand side of VELA goes from low to high (about 4 volts), and stays high for the duration of the data logging. This high output can be used to start an experiment running, and provides an alternative means of synchronising the data logging with the event being monitored.
8 When data logging starts, an oscilloscope connected to the analogue output display a constantly updated graph of the value of the channel 1 input against time.
Press 'CH 2' to display the data on channel 2, 'CH 3' to display the data on channel 3, etc. The VELA display shows the chosen channel number, the number of items of data that have been logged on that channel and the value of the last item logged.

To stop logging data: press 'STOP'. (Logging will stop automatically after 1023 items of data per channel have been recorder.)

Logging finished: This is indicated by 'O-P' on the display.

Output: The output instructions are given to VELA using the right hand half of the keypad.

1 On an oscilloscope

As explained on the previous page, a constantly updated oscilloscope trace is obtained with this program while data is being logged. When logging is finished, the oscilloscope display will turn off, and the following instructions must be used to obtain another trace.

a) Connect an oscilloscope to the output socket on the right of the instrument;
b) press 'CH 1',to display the channel 1 data, 'CH 2' to display the channel 2 data, and so on;
c) press 'SCOPE'; data stored in channel 1 will be displayed on the oscilloscope alternately with data stored in the chosen channel, thus giving a dual beam facility enabling the channel 1 data to be compared with data in any other channel. The oscilloscope timebase speed must be at least 2 milliseconds per division for this to work properly.
If channel 1 is chosen, then only the data in channel 1 is sent to the oscilloscope;
d) adjust the oscilloscope as necessary - see section 1.3;
e) to stop the output to an osciiloscope press 'RESELECT DISPLAY'. The VELA display will show 'O-P'. Another data block or display instrument can now be chosen.
f) while data is being sent to the oscilloscope, the right hand side of the VELA display shows the value of the first item of data logged on the chosen channel, ready for stepping through the data one item at a time (see below).

2 On a chart recorder

a) Connect a chart recorder to the output socket on the right hand side of VELA.
b) Adjust the chart recorder to appropriate speed and sensitivity (see section 1.4); switch the chart recorder on;
c) Press 'CH 1' to print out the channel 1 data, 'CH 2' to print out the channel 2 data, and so on;
d) Press 'CHART'; data will be read to the chart recorder. The VELA display will show which item is being read, together with its value;
e) When data transfer is finished, disconnect the chart recorder. The VELA display will show '0-P'. Another channel or display instrument can now be chosen.

3 One reading at a time on the VELA display

a) Press 'CH 1', 'CH 2', 'CH 3' or 'CH 4' to select which date channel is to be displayed. The chosen channel number will appear on the left of the display.
b) press 'SCOPE' (even if there is no oscilloscope connected); the chosen channel number will remain on the left of the display and the value of the first item in that channel will appear on the right of the display, and a '1' (first item) in the middle of the display;
c) press '>'; the channel number will flash momentarily on the left, the second item of data in that channel will be shown on the right, and a '2' ('second item') will appear in the middle. Press '>' again and the third item of data will be shown, and so on;
d) If the '<<>>' key is pressed at the same time as the '>' key, VELA will move forward by 16 items of data; this can be repeated by further simultaneous pressing of the '<<>>' and '>' key;
e) if an oscilloscope is connected, a small 'cursor' will move along the oscilloscope trace, marking on the trace which item of data is being displayed;
f) to move backwards through the data, use the '<' key instead of the '>' key.
g) when finished, press 'RESELECT DISPLAY'. The VELA display will show '0-P', and another channel of data or output instrument can be chosen.

4 Transfer of data to a microcomputer

It is necessary to program the microcomputer to receive the data. See the Technical Manual.

a) Connect the microcomputer to the digital socket on the right of VELA;
b) load and run the appropriate microcomputer program;
c) press 'CH 1', 'CH 2', etc according to which channel of data is to be transferred (see above);
d) press 'MICRO';
e) when data transfer is complete, The VELA display will show '0-P' and a new data channel or output instrument can be chosen.

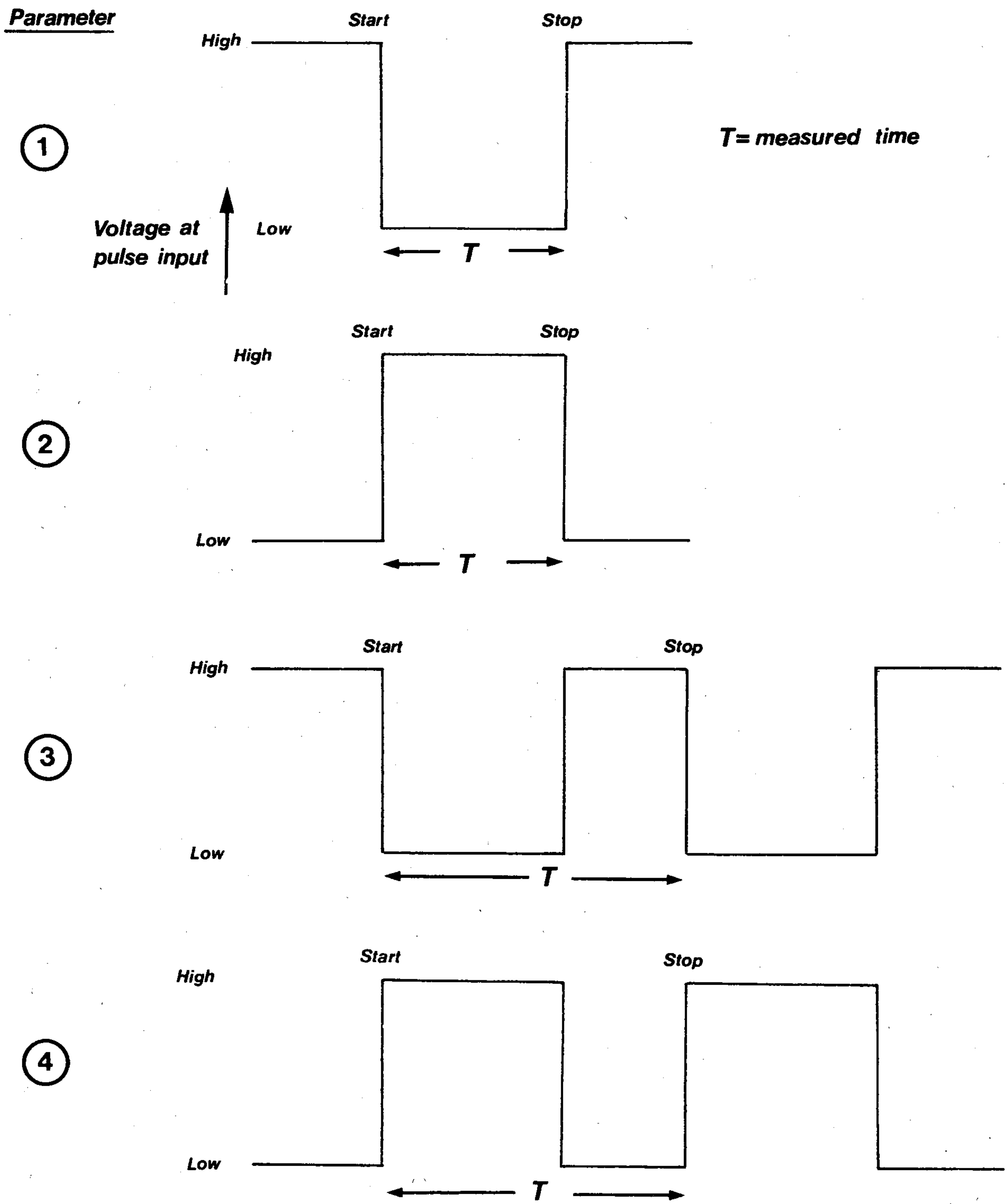
## FREQUENCY METER

| | |
|---|---|
| Description: | This program measures the frequency of pulses, or of a waveform, which can be of any regular shape. |
| Program number: | 04 |
| Parameter: | None |
| Input: | To pulse input. Input should be in the range +/-25 V. The signal should have a peak amplitude of at least +1 V. Signals of less than +1 V peak amplitude will first need amplifying, by connecting to the channel 1 input, selecting a suitable range with the three position range switch and switching the pulse input to 'internal'. |
| Frequency range: | 1Hz to 20Hz. VELA's display flashes 'HI' if the input frequency is too high to be measured. |
| To use this program: | 1 Make appropriate connections to the VELA pulse input if necessary via the channel 1 amplifier (see above);<br>2 press 'RESET';<br>3 press '04' to select the program number;<br>4 press 'ENTER'. |
| Output: | The frequency is displayed, in Hz, on the VELA display. This is updated once every second.<br>NOTE: The display shows the last non-zero count in any previous interval. |

## EVENT TIMER / STOPWATCH

| | |
|---|---|
| Description: | This program records the time between 'start' and 'stop' signals which can be sent either via the pulse input or from the 'START' and 'STOP' keys. |
| Program number: | 05 |
| Parameter: | 1, 2, 3 or 4. The default value is 1. This defines the kind of pulse which will start and stop the clock. See next page. |
| Input: | To the pulse input. The pulse must be in the range +/-25 V and should have a peak amplitude of at least +1 V. Signals of less then +1 V peak amplitude can be amplified by connecting them to the channel 1 input, and selecting a suitable range with the three position range switch. In this case the pulse input switch should be on 'internal', thus connecting the output from channel 1 amplifier to the pulse input. Refer to page for further details concerning pulse amplitudes needed for triggering. |
| Time range: | 1 millisecond to 65 seconds. |
| To use this program: | 1 Make appropriate connections to the VELA pulse input, if necessary via the channel 1 amplifier (see above);<br>2 Press 'RESET';<br>3 Type '05' to select this program;<br>4 Press a number in the range 1 to 4 to select the appropriate parameter (see below);<br>5 Press 'ENTER';<br>6 Timing will start when the 'START' key is pressed or when a starting pulse is received, and stop when the 'STOP' key is pressed or a stop pulse is received; the 'seconds' light on the display will flash at approximately 2Hz while timing is in progress;<br>7 There is no need to reset the timer for subesequent timings unless a different kind of start or stop pulse is required. There is a delay of 1 second before VELA can start timing again. |
| Output: | The time is displayed, in seconds, on the VELA display. If the time exceeded 65 seconds, VELA 'times out'; the display shows 'HI'; in this case it is necessary to press 'RESET' and start again. |
| Start and stop pulses: | The parameter (1 to 4) defines whether the VELA starts or stops timing as the input voltage goes from low to high (a positive going edge'), or as the input goes from high to low ('negative going edge'), as in the diagrams below. |

Regardless of the parameter, the 'START' key can be used to start the timing, and the 'STOP' key to stop the timing.


Parameter
1
2
3
4
Start
Stop
High
Low
T
T= measured time
Voltage at
pulse input

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## MULTI-CHANNEL TIMER

Description:

This program monitors up to 8 sensors and records.
a) The times at which any of the sensors changes state;
b) Which of the 8 sensors changes.
The sensors must give TTL compatible logic level signals, ie in the 'high' state must give an output in the range 3 to 5 V, and in the 'low' state an output in the range 0 to 0.5 V.

Program number: 06

Parameter: None

Input:

To 8 digital input lines, (lines PA0 to PA7), one sensor output being connected to each digital input. The input must be a TTL compatible logic signal as described above. Note that the digital input lines are not protected, and the use a buffer board (available separately) is strongly recommended.

Time range: 1 millisecond to 65.536 seconds.

To use this program:

1 Connect each sensor to a separate digital input line;
2 press 'RESET';
3 type '06' to select this program;
4 press 'ENTER'; the display will show the state of each of the input lines; for example, if each sensor is sending a 'high' signal to the input lines, the display will read 11111111;
5 press 'START' to start timing; the display clears and the seconds light will flash while timing is in progress;
6 to stop timing press 'STOP'; the program recycles from zero after 65.536 seconds.

Output:

1 On the VELA display
a) When timing has finished, press '>'. The display will show a series of eight digits, either 1 or 0, which shows the state of the sensors when timing started; the first digit shows the state of line PA7 ('most significant bit') and the last digit the state of line PA0 ('least significant digit').
For example, if the display shows 11111101, then all sensors were giving a 'high' output except sensor number 2 (connected to line PA1) which was giving a 'low' output.
b) Press '>' again. The display will show 'O'; this is the time (in seconds) at which the above 'sensor pattern' occurred, ie at the start
c) Press '>' again. The display will show the next 'sensor pattern' which occurred. eg 11111111, all sensors were giving a high output.
d) Press '>' for a fourth time. The display will show the time, in seconds, at which the sensor outputs changed to this pattern.
e) Pressing '>' further times gives successive sensor patterns and the times at which the sensors changed to that pattern.
f) After displaying the time at which the last change occurred, a further press of '  ' returns the display to the start of the sequence again.
g) Note that '<' does not operate with this program.

2 Transfer of data to a microcomputer
It is necessary to program the microcomputer to receive the data. See the Technical Manual.

a) Connect the microcomputer to the digital output socket on the right hand side of VELA.
b) Load and run the appropriate microcomputer program.
c) Now refer to program 15 - Transfer of data from VELA to a microcomputer.
d) the first byte of data is the decimal equivalent of the binary number which represents the state of the sensors (eg a number 3 represents a sensor pattern 00000011); the next two bytes represent the time at which this sensor pattern occurred.
e) when data transfer is complete, press 'RESELECT DISPLAY'.

## PULSE COUNTING

| | |
|---|---|
| Description: | This program is ideally suited to counting pulses which arrive in a random manner, for example pulses from radioactivity detecting equipment. It is better to use the 'frequency' program to count pulses which arrive at regular intervals, ie have a fixed frequency. |
| Program number: | 07 |
| Parameter: | 1 to 999. This defines the sampling interval in seconds. For example, a parameter of 10 will instruct the logger to record the number of pulses arriving in each successive 10 second interval. |
| Input: | To the pulse input. The input should be in the range +/-25 V. The signal should have a peak amplitude of at least +1 V. Signals of less than +1 V peak amplitude will need amplifying. This can be done by connecting the signal to the channel 1 input, and selecting a suitable range with the three position range switch. The pulse input switch should be on 'internal', which connects the output from the channel 1 amplifier to the pulse input. |
| Maximum data: | 255 readings. The count should not exceed 255 in any one sampling period. |
| To use this program: | 1 Make appropriate connections to the VELA pulse input if necessary via the channel 1 amplifier (see above);<br>2 press 'RESET';<br>3 type '07' to select this program;<br>4 use the keypad to type in the parameter, ie the time, in seconds, of the sampling interval (see above);<br>5 press 'ENTER'; the parameter will disappear from the display;<br>6 when ready to start recording, press 'START';<br>7 the sample number will appear on the display while data logging is in progress. An oscilloscope connected to the output will display a constantly updated graph of count rate against time. (See next page.) |
| To stop logging data: | Press 'STOP'. The display will show '0-P'. |
| Output: | The output instructions are given to VELA using the right hand half of the keypad. |

1 On an oscilloscope

An oscilloscope connected to the output displays a graph of 'counts per unit time' against 'time', where the 'unit time' is the time interval defined by the 'parameter'. This occurs automatically while data logging is in progress, providing a constant up-to-date picture of the results.

To obtain this graph after logging is completed, press 'CH1' then 'SCOPE'. If 'CH3' or 'CH4' is pressed the display will show the total number of counts received during the counting period.

To stop the output of the oscilloscope, press 'RESELECT DISPLAY'. The VELA display will show '0-P'. Another display instrument can now be chosen.

2 On a chart recorder

a) Connect a chart recorder to the output socket on the right hand side of the VELA;
b) Adjust the chart recorder to the appropriate speed and sensitivity (see section 1.4);
c) Press 'CH 1';
d) Press 'CHART'; data will now be read to the chart recorder. The VELA display will show which item is being transferred, together with its value;
e) when data transfer is finished, (after about 5 minutes), disconnect the chart recorder. The VELA display will show '0-P'. Another display instrument can now be chosen.

3 One reading at a time on the VELA display

a) Press 'CH 1';
b) Press 'SCOPE' (even if there is no oscilloscope connected); a '1' will appear on the left of the display (meaning 'first reading') and the value of the first reading logged will appear on the right of the display.
c) press ' > '; the second item of data will be shown on the VELA display. Press ' > ' again and the third item of data will be shown, and so on;
d) If the ' <<>> ' key is pressed at the same time as the ' >' key, VELA will move forwards by 16 items of data; this can be repeated by further simultaneous pressing of the ' <<>> ' and '>' key;
e) If an oscilloscope is connected, a small 'cursor' will move along the oscilloscope trace, marking on the trace which item of data is being displayed;
f) To move backwards through the data, use the ' < ' key instead of the ' > ' key.
g) When finished, press 'RESELECT DISPLAY'. The VELA display will show '0-P', and another display instrument can be chosen.

4 Transfer of data to a microcomputer

It is necessary to program the microcomputer to receive the data. See the Technical Manual.

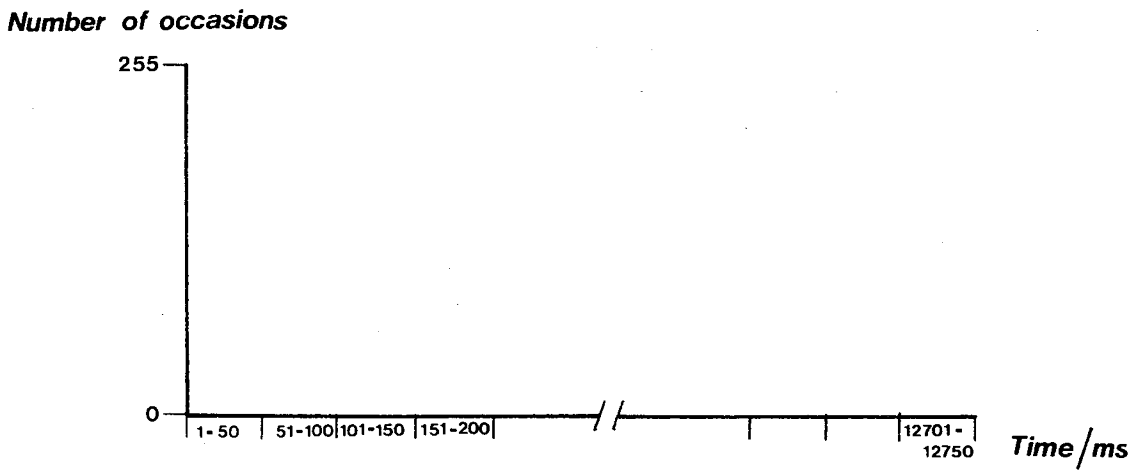
a) Connect the microcomputer to the digital socket on the right hand side of VELA;
b) Load and run the appropriate microcomputer program;
c) press 'CH 1';
d) press 'MICRO';
e) When data transfer is complete, the VELA display will show '0-P' and a new output instrument can be chosen.

## STATISTICS OF INTERPULSE TIMES

Description: This program measures and records the times between the arrival of pulses. The output to the oscilloscope is in the form of a distribution graph with 'number of occasions' plotted up the y-axis against 'time between pulses' plotted along the x-axis. The x-axis is divided into 255 divisions.
Each division on the x-axis covers a range of time, eg 1 to 10 ms, 11 to 20 ms, 21 to 30 ms, and so on. The actual range is defined by a parameter typed in by the user.
The scale on the y-axis is from 0 to 255. Counting automatically stops when any one 'number of occasions' reaches 255.
The program is ideally suited to examining the distribution of interpulse times when the pulses arrive at random (eg from experiments involving radioactivity).

Program number: 08

Parameter: 1 to 999. This defines the time range, in tens of milliseconds,of each division on the x-axis of the distribution graph. For example, a parameter of 5 sets up the axes of the distribution graph as illustrated below.




Input: To the pulse input The input should be in the range +/-25 V. The signal should have a peak amplitude of at least +1 V. Signals of less than +1 V peak amplitude will need amplifying. This can be done by connecting the signal to the channel 1 input, and selecting a suitable range with the three position range switch. The pulse input switch should be on 'internal', which connects the output from the channel 1 amplifier to the pulse input.

Maximum data: This is limited only by the fact that logging stops when the maximum height of the graph is 255 occasions.

To use this programme:

1 Make appropriate connections to the VELA pulse input, if necessary via the channel 1 amplifier (see 'input' on previous page);
2 Press 'RESET';
3 Type '08' to select this program;
4 Using the keypad, type the parameter, ie the time range, in tens of milliseconds, represented by each point on the x-axis of the distribution graph;
5 Press 'ENTER'; the parameter disappears from the display;
6 When ready to start recording, press 'START';
7 The total number of pulses counted will appear on the right hand side of the display while data logging is in progress.
An oscilloscope connected to the output will display a constantly updated graph of the distribution of the inter-pulse times as described on the previous page.

**To stop logging data:** Press 'STOP'. The total number of pulses will continue to be displayed. Logging will stop automatically when the maximum height of the distribution graph reaches 255 counts. The program will also stop automatically if the time between arrival of pulses is greater than 255 multiplied by the parameter number in tens of milliseconds; for example if the parameter was 1 then the program would stop if the interpulse time exceeded 2550 milliseconds.

**Output:** The output instructions are given to VELA using the right half of the keypad.

1 On an oscilloscope

An oscilloscope connected to the output displays a graph of "number of occasions" against "interpulse time". This occurs automatically while date logging is in progress, providing a constant up-to-date picture of the results.

To obtain this graph after logging is complete, press 'CH1' then 'SCOPE'. If 'CH2', 'CH3' or 'CH4' is pressed the total number of counts logged is shown on the display.

To stop output of the oscilloscope, press 'RESELECT DISPLAY'. The VELA display will show '0-P'. Another display instrument can now be chosen.

2 On a chart recorder

a) connect a chart recorder to the output socket on the right hand side of the instrument;
b) adjust the chart recorder to the appropriate speed and sensitivity (see section 1.4);
c) press 'CH 1';
d) press 'CHART'; data will now be read to the chart recorder. The VELA display will show which item is being transferred, together with its value;
e) when data transfer is finished, (after about 5 minutes), disconnect the chart recorder. The VELA display will show '0-P'. Another channel or display instrument can now be chosen.

3 One reading at a time on the VELA display

a) Press 'CH 1';
b) Press 'SCOPE' (even if there is no oscilloscope connected); a '1' will appear on the left of the display (meaning 'first reading') and the value of the first reading logged will appear on the right of the display.
c) press ' > '; the second item of data will be shown on the VELA display. Press ' > ' again and the third item of data will be shown, and so on;
d) If the ' <<>> ' key is pressed at the same time as the ' > ' key, VELA will move forwards by 16 items of data; this can be repeated by further simultaneous pressing of the ' <<>> ' and ' > ' key;
e) If an oscilloscope is connected, a small 'cursor' will move along the oscilloscope trace, marking on the trace which item of data is being displayed;
f) To move backwards through the data, use the ' < ' key instead of the ' > ' key.
g) When finished, press 'RESELECT DISPLAY'. The VELA display will show '0-P', and another output instrument can be chosen.

4 Transfer of data to a microcomputer

It is necessary to program the microcomputer to receive the data. See the Technical Manual.

a) Connect the microcomputer to the digital socket on the right hand side of VELA;
b) Load and run the appropriate microcomputer program;
c) press 'CH 1';
d) press 'MICRO';
e) When data transfer is complete, The VELA display will show '0-P' and a new output instrument can be chosen.

## STATISTICS OF RANDOM EVENTS

**Description:** This program records the distribution of pulse rates. The output to the oscilloscope is in the form of a distribution graph, with 'number of occasions' plotted up the y-axis against 'counts per specified sampling time' along the x-axis. The scales of both axes are from 0 to 255. Counting automatically stops as soon as any one 'number of occasions' reaches 255. The program is ideally suited to random events, such as radioactive decay rates, where large quantities of data are required before any conclusion can be drawn.

**Program number:** 09

**Parameter:** 1 to 999. This defines the sampling interval in seconds. For example, a parameter of 5 will instruct the logger to record the number of pulses arriving every successive 5 seconds.

**Input:** To pulse input. The input should be in the range +/-25 V. The signal should have a peak amplitude of at least +1V. Signals of less than +1V peak amplitude will need amplifying. This can be done by connecting the signal to the channel 1 input and selecting a suitable range with the three position range switch. The pulse input switch should be on 'internal', which connects the output from the channel 1 amplifier to the pulse input.

**Maximum data:** The count should not exceed 255 in any one sampling time.

**To use this program:**

1 Make appropriate connections to the VELA pulse input, if necessary via the channel 1 amplifier (see above);
2 Press 'RESET';
3 Type '09' to select the program;
4 Use the keypad to type in the parameter, ie the time, in seconds, of the sampling interval (see above);
5 Press 'ENTER'; the parameter disappears from the display;
6 When ready to start recording, press 'START';
7 The sample number will appear on the display while data logging is in progress. An oscilloscope connected to the output will display a constantly updated graph of the distribution of the count rates as described at the top of this page.

**To stop logging data:** Press 'STOP'. The total number of counts will then be displayed. Logging will stop automatically when the peak of the distribution graph reaches 255 occasions.

**Output:** The output instructions are given to VELA using the right hand half of the keypad.

1 On an oscilloscope

An oscilloscope connected to the output displays a graph of (number of occasions) against (count rate), as described at the top of the previous page. This occurs automatically while data logging is in progress, providing a constant up-to-date picture of the results.

To obtain this graph after logging is complete, press 'CH1' then 'SCOPE'.

To stop the output of the oscilloscope, press 'RESELECT DISPLAY'. The VELA display will show '0-P'. Another display instrument can now be chosen. With this program the choice of display instrument can be varied during the logging of data; after transferring data to a chart recorder or microcomputer, press 'START' to continue collecting data.

The oscilloscope may exhibit slight jitter when the program is running. However, it is very stable after pressing 'STOP'.

2 On a chart recorder

a) Connect a chart recorder to the output socket on the right hand side of the instrument;
b) Adjust the chart recorder to the appropriate speed and sensitivity (see section 1.4);
c) press 'CH 1';
d) Press 'CHART'; data will now be transferred to the chart recorder; The VELA display will show which item is being transferred, together with its value;
e) When data transfer is finished, (after about 5 minutes), disconnect the chart recorder. The VELA display will show '0-P'. Another display instrument can now be chosen.

3 One reading at a time on the VELA display

a) Press 'CH 1';
b) Press 'SCOPE' (even if there is no oscilloscope connected); a '1' will appear on the left of the display (meaning 'first reading') and the value of the first reading logged will appear on the right of the display.
c) press ' > '; the second item of data will be shown on the VELA display. Press ' > ' again and the third item of data will be shown, and so on;
d) If the '<<>>' key is pressed at the same time as the ' > ' key, VELA will move forwards by 16 items of data; this can be repeated by further simultaneous pressings of the '<<>>' and '>' key;
e) If an oscilloscope is connected, a small 'cursor' will move along the oscilloscope trace, marking on the trace which item of data is being displayed;
f) To move backwards through the data, use the '<' key instead of the '>' key.
g) When finished, press 'RESELECT DISPLAY'. The VELA display will show '0-P', and another display instrument can be chosen.

4 Transfer of data to a microcomputer

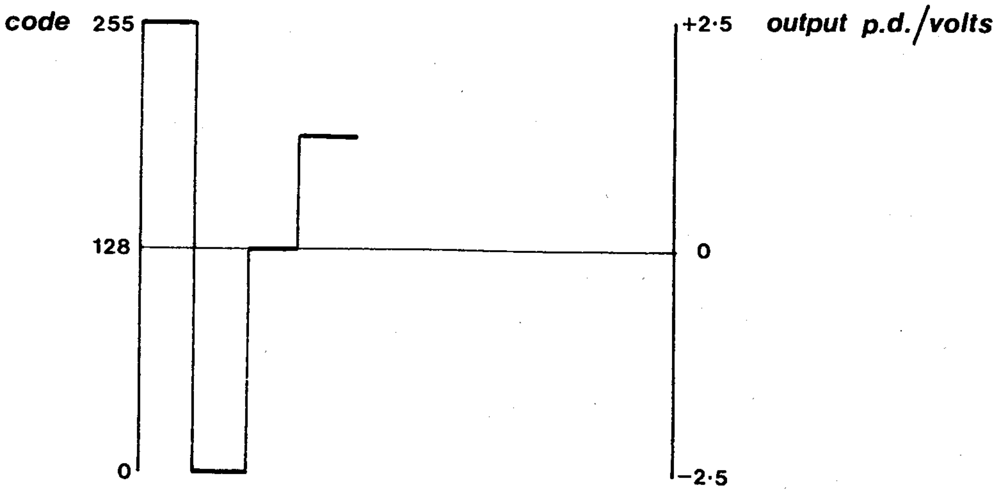
It is necessary to program the microcomputer to receive the data. See the Technical Manual.

a) Connect the microcomputer to the digital socket on the right of VELA;
b) Load and run the appropriate microcomputer program;
c) press 'CH 1';
d) press 'MICRO';
e) When data transfer is complete, The VELA display will show '0-P' and a new output instrument can be chosen.

## VERSATILE WAVEFORM GENERATOR

| | |
|---|---|
| Description: | Using this program a user can build up a waveform of any shape and duration. The waveform is available in analogue form at the analogue output, and in digital form from the eight digital output lines. |
| Program number: | 10 |
| Parameter: | 0 to 999. This defines the time in milliseconds between each code output. A parameter of 0 enables VELA to work 'flat out', with approximately 80 microseconds between codes. If no parameter is typed, VELA will default to 1 ms between codes. |
| Input: | From the keypad; numbers between 0 and 255. |
| Maximum data: | 1024 steps. |
| To use this program: | 1 Connect your experiment or oscilloscope to the output socket or digital output as appropriate;<br>2 Press 'RESET';<br>3 Type '10' to select this program;<br>4 Use the number pad to type in the parameter, ie the time in milliseconds betwen the output of each code (see below);<br>5 Press 'ENTER';<br>6 The display will now show '1' in the middle, and 'xyz' on the right, meaning that the contents of memory location 1 is 'xyz'; use the keypad to type in the code required to replace xyz;<br>7 Press 'ENTER'; your code is now entered into location 1;<br>8 A voltage proportional to the code will appear at the analogue output, and the binary form of that number will appear on the digital output lines. The current output capability of the analogue output socket is limited by 600 ohm impedance. |

For example, a code of 255 will give 2.5 V at the analogue output, and all the digital lines will go high, a code of 0 will give -2.5 V and all digital lines low; a code of 128 will give 0 V and the state of the digital lines will be 10000000; a code of 192 will give 1.25 V and the state of the digital lines will be 11000000, and so on. See the diagram below.
At the same time, one or more of the three leds in the display may come on; these leds will reflect the three most significant bits of the code.



9 Press '>' to move to the next memory location, and enter the code you require in that memory location; '<' can be used to move back through memory in the same way.
10 As the codes are entered, an oscilloscope connected to the output displays the waveform that is being built up; the oscilloscope screen will look similar to the diagram above;
11 After entering all the required codes, press 'START'; the codes will appear repetitively on both the analogue output and the digital output lines; the time for which each code is present on these output lines is determined by the parameter entered at stage 4 above.
NB VELA will assume that the last code entered is the end of the sequence; if you go back to make an alteration, you must then step forwards again to the end of the sequence before pressing 'START'; the last code entered remains on the display;
12 to alter any codes,
a) press 'RESELECT DISPLAY'; the output stops;
b) press 'SCOPE';
c) press '>' or '<' as appropriate to move to the relevant code;
d) alter the code as explained above;
e) after making all the required alterations, use the '>' key to step through to the final code before pressing 'START' again;
13 to change the time between the output of each code,
a) press 'RESELECT DISPLAY'; the output stops;
b) type the new time required;
c) press 'ENTER'; the output will start again automatically.

Output: At the analogue output and in binary coded form on the digital lines as described above.

NOTE

If 'RESET' is pressed in error, the codes remain in the memory. The codes can be recovered in two ways.

(i) A second eprom, ISL2*, is available from the manufacturers which allows the user to re-enter this and any of the other data-logging routines.
(ii) Type '16 ENTER* and enter the following decimal codes:
127, ENTER, '>', 0, ENTER, '>', 35, ENTER, '>' 126, ENTER, '>', 244, ENTER, '>', 61, ENTER, '>', START
(iii) Routines in Eprom that allow data tables to be created on a micro-computer and then downloaded to VELA for subsequent waveform generation are also available - contact the manufacturers.

## CONTROL SEQUENCE GENERATOR

Description: This program works in a similar way to the previous one - Versatile Waveform generator but the time between codes is longer and the code sequence is given out only once, rather than repetitively. Using this program a user can build up a sequence of codes, which can then be given out in analogue form at the analogue output, and in digital form from the eight digital output lines.

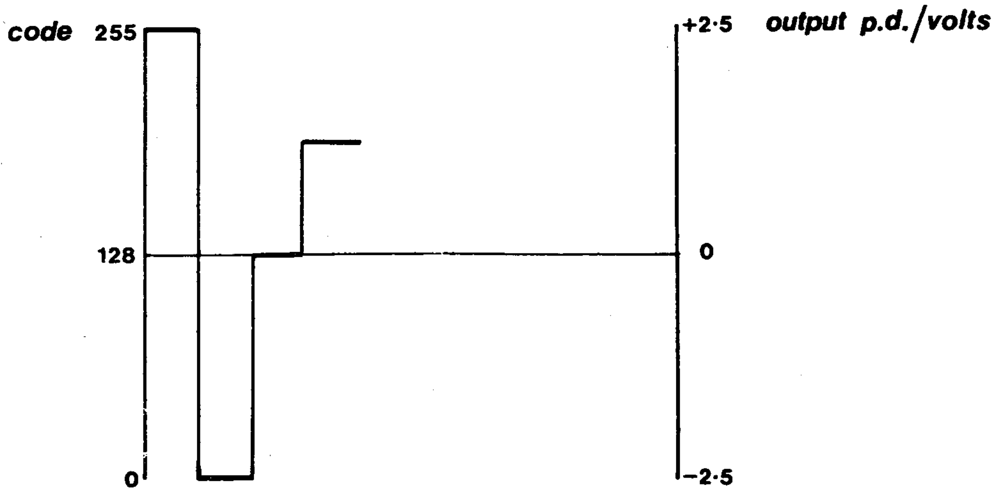
Program number: 11

Parameter: 1 to 999. This defines the time in seconds between each code output. If no parameter is typed, VELA will default to 1 s between codes.

Input: From the keypad; numbers between 0 and 255.

Maximum data: 1024 steps.

To use this program: 1 Connect your experiment or oscilloscope to the output socket or digital output as appropriate;
2 Press 'RESET';
3 Press '11' to select this program;
4 Use the number pad to type in the parameter, ie the time in seconds between the output of each code (see below);
5 Press 'ENTER';
6 the display will show '1' on the left and 'xyz' on the right, meaning that the contents of memory location 1 is xyz; use the keypad to type in the code required.
7 Press 'ENTER'; your code is now stored in memory location 1.
8 A voltage proportional to the code will appear at the analogue output, and the binary form of that number will appear on the digital output lines.
For example, a code of 255 will give 2.5 V at the analogue output, and all the digital lines will go high, a code of 0 will give -2.5 V and all digital lines low; a code of 128 will give 0 V and the state of the digital lines will be 10000000; a code of 192 will give 1.25 V and the state of the digital lines will be 11000000, and so on. See the diagram below.
At the same time, one or more of the three leds in the display may come on; these leds will reflect the three most significant bits of the code.



9 Press '<' to move to the next memory location, and enter the code you require in that memory location; '<' can be used to move back through memory in the same way.

10 As each code is entered, the binary form of that code is available to the digital output lines; an oscilloscope connected to the analogue output displays the waveform that has so far been built up; the oscilloscope trace will look similar to the diagram above.

11 After entering all the required codes, press 'START'; the codes will be output repetitively on both the analogue output and the digital output lines; the time for which each code is present on these output lines is determined by the parameter entered at stage 4 above.

N.B. VELA will assume that the last code entered is the end of the sequence; if you go back to make an alteration, you must then step forwards again to the end of the sequence before pressing 'START'; the last code entered remains on the display;

12 to alter any codes,
a) press 'RESELECT DISPLAY'; the output stops;
b) press 'SCOPE';
c) press '>' or '<' as appropriate to move to relevant code;
d) alter the code as explained above;
e) after making all the required alterations, use the '>' key to step through to the final code before pressing 'START' again;

13 to change the time between the output of each code,
a) press 'RESELECT DISPLAY'; the output stops;
b) type the new time required;
c) press 'ENTER'; the output will start again automatically.

Output: At the analogue output and in binary coded form on the digital lines as described above.

NOTE

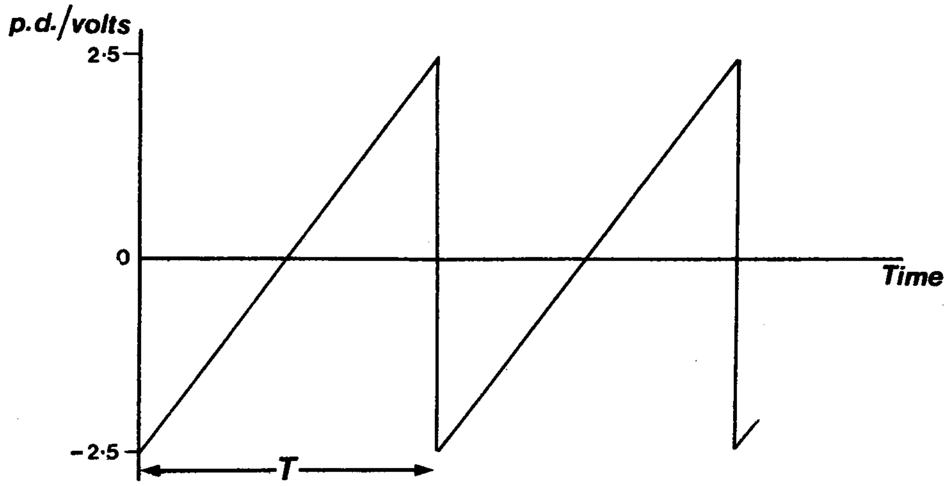
If 'RESET' is pressed in error as the codes remain in memory, they can be recovered and the output restarted as follows:

press '11 parameter ENTER';

step through the memory locations to the last code; press 'START'.

## RAMP GENERATOR

Description: This program generates a voltage 'ramp' at the output socket ie a voltage which steadily increases from -2.5V to +2.5 V, as in the graph below, with a period 'T' of 2.6 ms. This ramp output repeats continuously until the program is stopped by pressing 'RESET'.




Program number: 12

Parameter: None

To use this program:

1 Press 'RESET';

2 Press '12' to select this program;

3 Press 'ENTER';

Output: From the output socket. Note that the maximum current that can be supplied is small (about 4 mA) and that this may need amplifying for some applications.

## TO TRANSFER DATA FROM VELA TO A MICROCOMPUTER

Description:

This program transfer the contents of the RAM to a microcomputer (which, in turn, could store the data on tape or disc, or process the data in some way). It can be used, for example, to transfer a user's own program or codes from the Versatile Waveform Generator program.

Note that the facility provided by this program already exists at the touch of a key with all the data logging programs in VELA.

This program is of particular use when data has been stored in RAM using the battery back-up facility mentioned in section 1.1. This program enables the stored information to be retrieved from the RAM when VELA is powered up again (assuming the back up battery is adequately charged.)

Program number: 15

To use this program:

1 press 'RESET';

2 Type '15' to select this program;
3 Press 'ENTER';
4 Connect the microcomputer to the digital socket on the right hand side of VELA;
5 Load and run the appropriate microcomputer program (see the Technical Manual for further details);
6 Press 'MICRO'.

## USER PROGRAM CREATION

| | |
|---|---|
| Description: | Using this program, a user's own set of instructions can be entered into the instrument. |
| Program number: | 16 |
| Parameter: | None |
| Input: | From the keyboard. Any number in the range 0 to 255. |
| Maximum data: | 1023 codes can be entered. |
| Output: | The user must define this in the program being written. |

Full details of how to write instructions for VELA are in the Technical Manual which accompanies VELA.

# Technical Manual

# VELA
# TECHNICAL MANUAL

## CONTENTS

# 1 INTRODUCTION

Our primary aim in developing VELA was to provide a microprocessor-based laboratory tool which could be easily operated by non-specialists in computing.

The VELA is easy to operate. A two digit program number must be typed in to tell the microprocessor which measurement is required. Some measurements require a one, two or three digit parameter value to specify VELA's function uniquely. After typing in the parameter value, type 'ENTER' and the appropriate routine is called from the onboard memory integrated circuit. The VELA will then perform the task. In this way, with the minimum of fuss, previously tedious measurements may be left to the VELA to acquire and store unattended.

The USER manual is desgined to spell out in the simplest possible terms the sequence of key presses and the likely responses for each of the 17 programs supplied with the basic VELA unit. This TECHNICAL manual is designed to be an adequate technical description of the VELA so that readers who already possess a working knowledge of machine code programming and computer system architecture can begin to create their own programs.

Additional programs have been developed by the manufacturers and a complete is available on request.

# 2 DESCRIPTION OF OPERATION

## 2.1 Review of Microcomputer System

Every microcomputer system is essentially composed of a large number of memory elements. Each memory element is in one of two states - either a high (1) state or a low (0) state. In the VELA's microcomputer system the memory elements are organized into words of 8 elements and each word is located within the system by a unique memory address. Each word is therefore an 8 bit (binary digit) code which may be interpreted as either data or a special coded instruction. The function of a microcomputer system is to execute (ie carry out) a program (ie a time ordered sequence of coded instructions) in order to solve a problem. The program execution is controlled by a very large scale integration (VLSI) chip or integrated circuit called the Central Processor Unit (CPU) operating at a crystal controlled frequency, f = 1 MHz.

There are different types of memory element within a microcomputer system. Clearly, a supervisory (or monitor) program must take control of the system as soon as the power is applied - otherwise the user would be unable to make the system solve the particular problem at hand. The list of instructions which constitute the monitor program are stored in a type of read only memory (ROM) whose contents cannot be scrambled or altered by the removal of power. However, when the microcomputer is performing calculations on data another type of memory is required - namely, memory which can not only be read but also redefined. This is called random access memory (RAM). A practical microcomputer system nowadays may consist of the interconnection of a small number of integrated circuits, each of which is linked to a 'data bus' of 8 tracks (onto which the voltage levels corresponding to the 8 bit codes are placed) and an 'address bus' of up to 16 tracks (onto which the voltage levels corresponding to a 16 bit address code are placed).

The usual way of representing the 16 bit address code is as a four digit hexadecimal (base sixteen) code. The hexadecimal digits and the equivalent binary code are shown in Table 1. The lowest memory address is therefore $0000 and the highest memory address is (where the $ prefix indicates that the code is a hexadecimal code). In every microcomputer system, certain memory addresses are not used. The system 'memory map' gives an overview of the function of blocks of memory and their addresses.

When a scientific measurement is made, it is usually of a smoothly varying analogue voltage at the output of a suitable sensor or transducer. The microcomputer system can only store and process binary codes. Therefore, it is necessary to convert the analogue voltage value (at the instant when the measurement is to be made) into an 8 bit code suitable for storage in one of the system memory locations. The integrated circuit which carries out this task is the ADC (analogue to digital converter) and usually the digital code (in terms of voltage levels on 8 tracks) is connected into the microcomputer system via a special purpose interface integrated circuit. The most common interface chip for Motorola based systems is the Peripheral Interface Adaptor (PIA) which has 16 data lines so that up to 16 data bits can be inputted to or outputted from the microprocessor system. Also the PIA has 4 control lines which can be programmed to sense a voltage transition or to generate voltage pulses.

Similarly, after the data logging has finished, it is often necessary to reconstruct graphically the time varying analogue voltages on an oscilloscope or chart recorder. The 8 bit codes stored in the microcomputer memory must be converted back to analogue voltage levels. The integrated circuit which carries out this task is the DAC (digital to analogue converter). One PIA may therefore act as the interface between an 8 bit ADC and an 8 bit DAC and two of the four control lines may be used to tell the ADC when to digitize and to sense when the ADC has finished the digitization.

| HEXADECIMAL DIGIT | EQUIVALENT BINARY |
|---|---|
| 0 | 0000 |
| 1 | 0001 |
| 2 | 0010 |
| 3 | 0011 |
| 4 | 0100 |
| 5 | 0101 |
| 6 | 0110 |
| 7 | 0111 |
| 8 | 1000 |
| 9 | 1001 |
| A | 1010 |
| B | 1011 |
| C | 1100 |
| D | 1101 |
| E | 1110 |
| F | 1111 |

TABLE 1

2.2 Overview of the VELA System

The circuit diagrams of the VELA is shown in figures 1 and 2. A full wave bridge rectifier and regulator chip ensure that the stabilised +5 volts is obtained from either AC (8 volts - 9 volts) or DC (8 volts-13.5 volts). It is not advisable to exceed the upper limit because the current drawn by the VELA is between 0.45 and 0.6 amps (depending upon the number of 7 segment displays activated) and the power dissipated in the regulator will become excessive. The design therefore allows the VELA to be operated by 4AH Nicad's on field trips or a low voltage supply in the laboratory. A mains adaptor is supplied with the instrument. Note that, if the VELA is powered by a low voltage dc supply, the polarity of the power leads is unimportant.

The complete list of active integrated circuits is given in Table 3. Every IC requires +5 volts and some require a -5 volt power rail too. This -5 volt rail is provided by a charge pump diode network - see figures 1 and 2. Because of the limitation to the output current drawn from this circuit, it is essential that low power operational amplifiers (TL061 and TL064) are used rather than the more common higher power versions (eg TL081 and TL084).

The VELA has one printed circuit board. The PCB and the layout of the active components is shown in figure 4. The full list of integrated circuits is given in Table 3. If the user is interested in low power operation, the 6821 PIA ic's could be replaced by pin compatible 6321 PIA's, or equivalent, (and this would reduce the power consumption to approximately 300 mA). Further power reductions could be obtained by using a CMOS EPROM (contact the manufacturers for details).

The PCB is connected to the touch sensitive keypad via a flexible multitrack strip. (for information on the replacement of EPROM's see section 2.3.)

The VELA is based on the Motorola 6802 central processor unit which has an on chip oscillator and 127 dec RAM locations. The software is held in eraseable, programmable, read only memories (EPROMs) which means that the software defining all of the VELA functions is up and running when power is supplied. The initial software contains 4096 8 bit codes in IC26. The VELA has 4096 RAM memory locations provided by the two 6116 integrated circuits, and it interacts with the outside world via 3 PIAs. The VELA memory map is shown in figure 5. Each PIA contains six registers and their hexadecimal addresses are shown in Table 2.

| HEXADECIMAL ADDRESS | REGISTER NAMES |
|---|---|
| \$X000 | Output Register A (and Data Direction Register A) |
| \$X001 | Output Register B (and Data Direction Register B) |
| \$X002 | Control Register A ($b_z$ = 0 selects DDRA, $b_z$ = 1 selects 0RA) |
| \$X003 | Control Register B ($b_z$ = 0 selects DDRB, $b_z$ = 1 selects ORB) |

'X' stands for C, D and E

TABLE 2

| ACTIVE DEVICE DESIGNATION | DESCRIPTION | PART NUMBER |
|---|---|---|
| ICI | 8 DIGIT, 7 SEGMENT ENCODER/DRIVER | ICM7218C1J1 |
| IC2 | HEX INVERTING SCHMITT TRIGGERS | 7414 |
| IC3 | DUAL OP AMP (LOW POWER) | TL062 |
| IC4 | QUAD OP AMP (LOW POWER) | TL064 |
| IC5 | OP AMP (LOW POWER) | TL061 |
| IC6 | OP AMP (LOW POWER) | TL061 |
| IC7 | OP AMP (LOW POWER) | TL061 |
| IC8 | OP AMP (LOW POWER) | TL061 |
| IC9 | 8 INPUT ANALOG SWITCH | 4051 |
| IC10 | HEX INVERTING BUFFER | 4049 |
| IC11 | QUAD 2-INPUT AND | 7408 |
| IC12 | ADDRESS DECODER | 74138 |
| IC13 | QUAD 2-INPUT NAND | 7400 |
| IC14 | CENTRAL PROCESSOR UNIT | 6802 |
| IC15 | PERIPHERAL INTERFACE | 6821 |
| IC16 | KEYBOARD DECODER | 74C922 |
| IC17 | PERIPHERAL INTERFACE | 6821 |
| IC18 | DIGITAL TO ANALOG CONVERTER | ZN429 |
| IC19 | ANALOG TO DIGITAL CONVERTER | ZN447/448 |
| IC20 | PERIPHERAL INTERFACE | 6821 |
| IC21 | RAM (2 k x 8) | 6116 (or equivalent) |
| IC22 | RAM (2 k x 8) | 6116 (or equivalent) |
| IC23 * | EXPANSION EPROM | 2732 |
| IC24 * | EXPANSION EPROM | 2732 |
| IC25 * | EXPANSION EPROM | 2732 |
| IC26 | FIRMWARE EPROM (4 k BYTES) | 2732 |

* Not supplied with the Basic Unit - (EPROM's are single rail devices)

TABLE 3

A List of Integrated Circuits Inside VELA

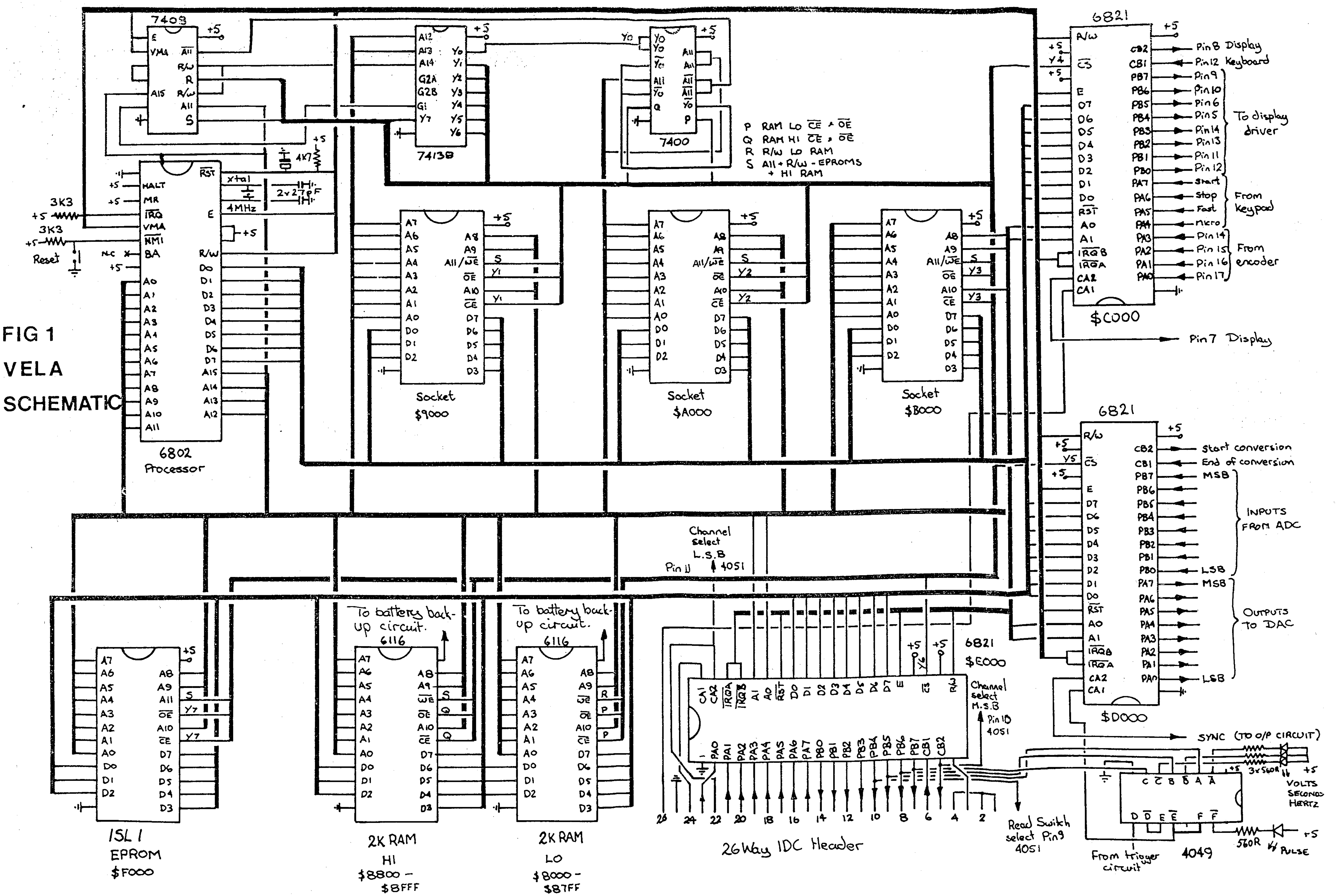
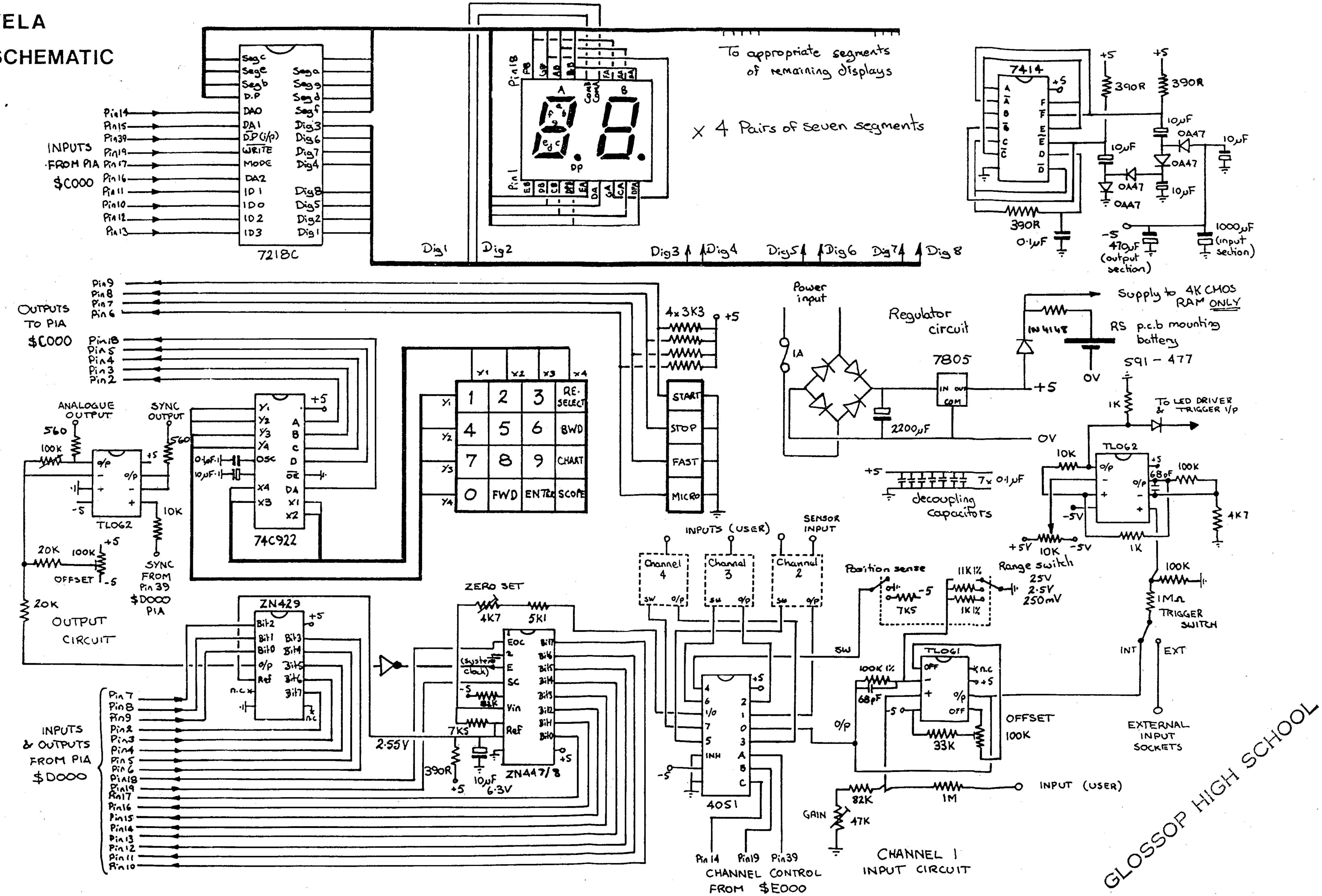



**FIG 1**

**VELA**

**SCHEMATIC**

**FIG 2**
**VELA**
**SCHEMATIC**



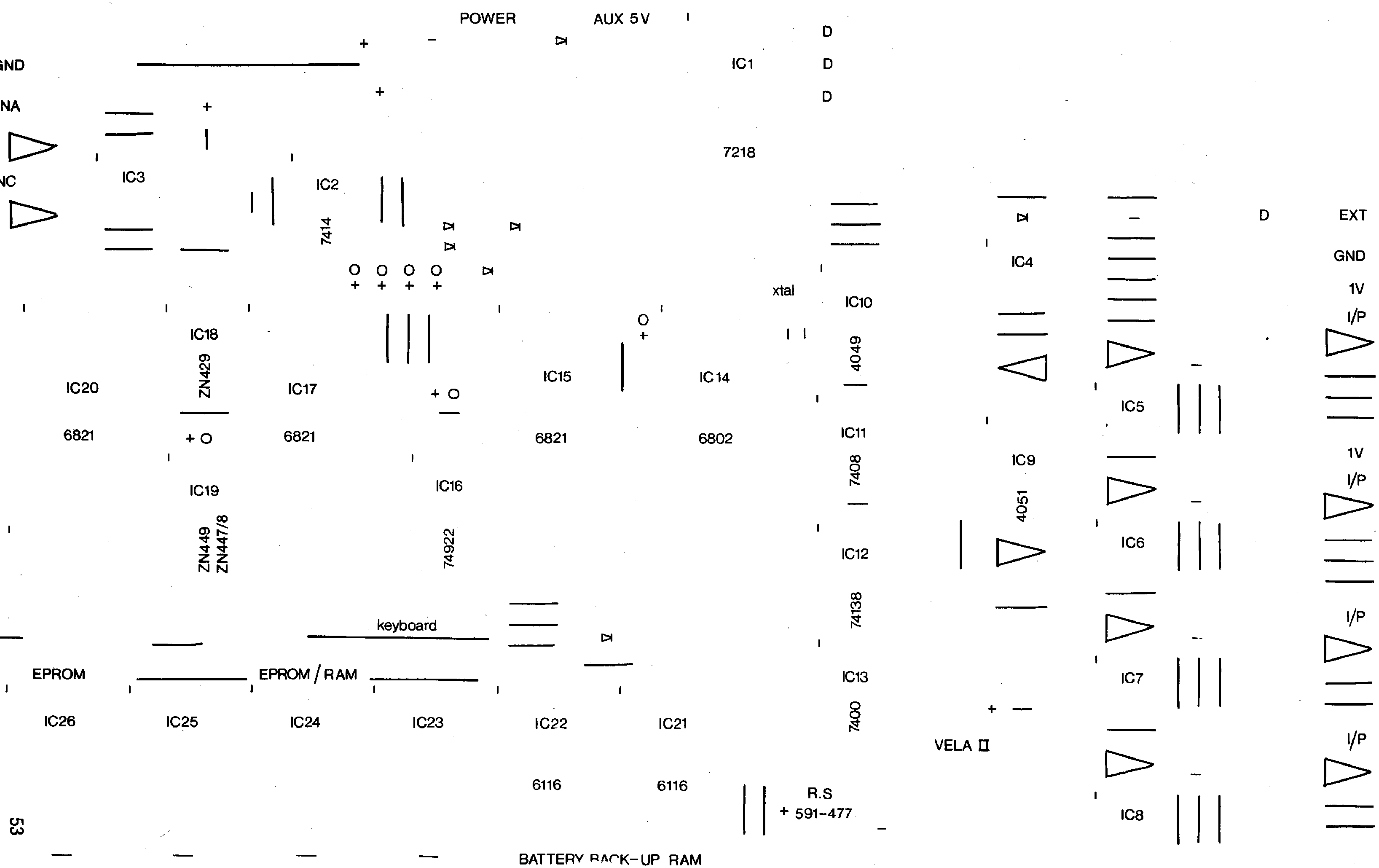



fig 4 PCB & Component Layout

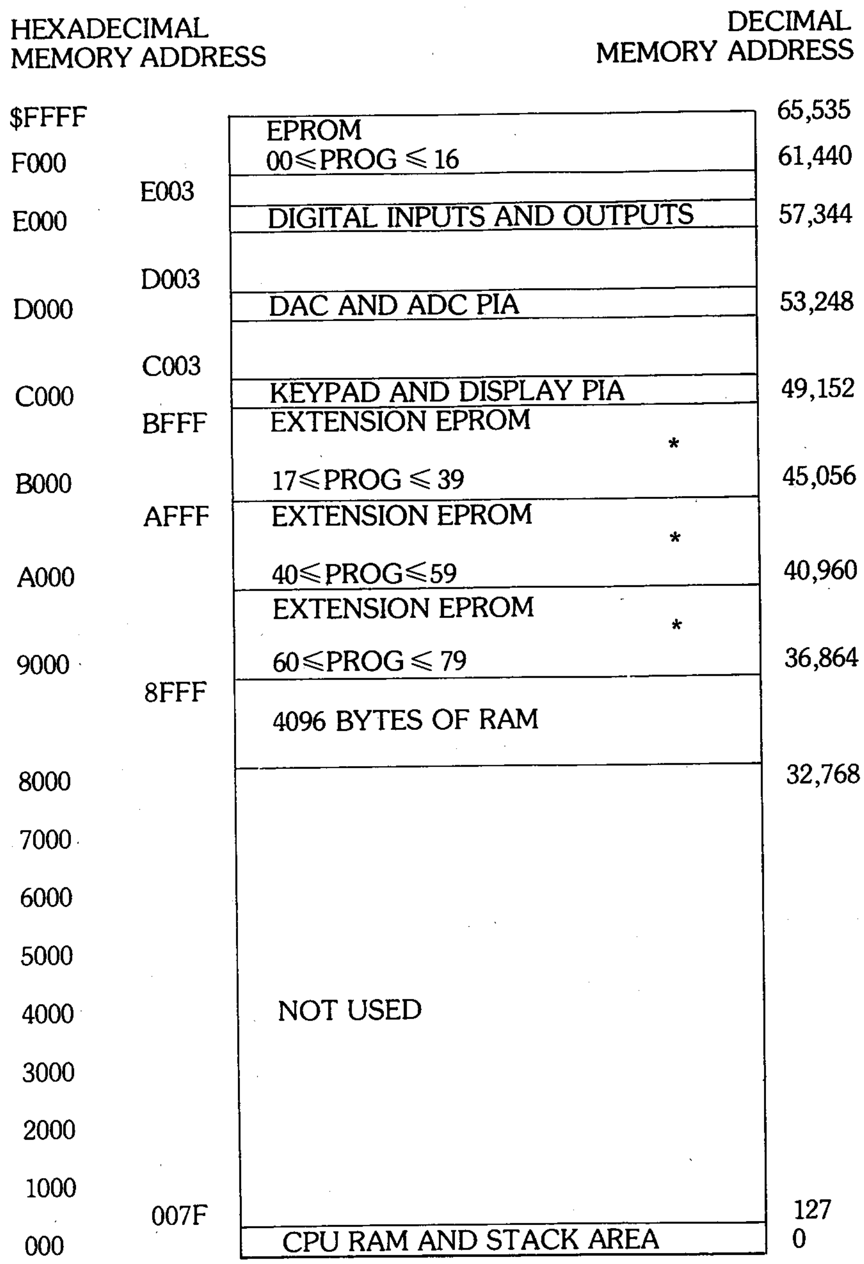



FIGURE 5: VELA MEMORY MAP

* A 6116 RAM chip could be used in place of any EPROM. (The RAM MEMORY defined being $9800-$9FFF, $A800-$AFFF or $B800-$BFFF.)

A more complete description of the function of the PIA data lines and the control lines is given in Table 4. When power is applied to the VELA, the CPU initialises the PIA's, defines the stack at the top of the CPU RAM space, ie the Stack Pointer is $007B, displays 'HELLO' for a few seconds and then the 'program request' prompt "P-" is displayed. If the user requests a program number between 00 and 16 dec, the CPU picks up the vector address of the appropriate routine from a pair of consecutive memory locations between $FA00 and $FA22. (If the user accidentally requests a program number outside this range, the VELA will react in an unpredictable way - until further EPROM's have been inserted, see section 2.3. In order to regain control, either press RESET or, if this does not give "P-" on the display, switch the power off and start again.)

| PIA HEXADECIMAL ADDRESS | DATA OR CONTROL | FUNCTION |
|---|---|---|
| $C000 | 8 DATA | Inputs from keypad and 74C922 |
| $C001 | 8 DATA | Outputs to display driver |
| SC002 | CA1 | Digital control input |
| | CA2 | DP output to display driver |
| $C003 | CB1 | Data available pulse input from 74C922 |
| | CB2 | Write pulse to display driver |
| $D000 | 8 DATA | Outputs to DAC |
| $D001 | 8 DATA | Inputs from ADC |
| $D002 | CA1 | Pulse input |
| | CA2 | Sync output |
| $D003 | CB1 | End of conversion (from ADC) |
| | CB2 | Start Conversion (to ADC) |
| $E000 | 8 DATA | Digital inputs |
| $E001 | 8 DATA | Digital outputs (& LED drivers) |
| $E002 | CA1 | Digital control input |
| | CA2 | Select analogue channel |
| $E003 | CB1 | Digital control input |
| | CB2 | Select analogue channel |

TABLE 4

Each of the four analogue inputs and the pulse input has an input impedance of approximately 1 MΩz in order to minimize the loading on external sensors. The incoming analogue signals are first attenuated by a factor x10 before being amplified by x1, x10 or x100. Each of these inputs is therefore protected against input voltages of up to +/-50 volts, and the three switched gain settings give effectively, a dynamic range of +/-250 millivolts, +/-2.5 volts and +/-25 volts. The software senses the manual switch positions and automatically adjusts the displayed decimal point for the digital voltmeter (program '00') and transient recorder programs (01, 02, 03). Note, however, that the maximum voltage swing at the 4 mm "scope output" socket is +/-2.5 volts and therefore, if the middle gain range has been selected during data logging programs, the voltages replayed to the oscilloscope will be facsimilies of the input waveform.

Because of the relatively high input impedance of the analogue and pulse channels, it is possible that there may be crosstalk or interaction between the pulse channel and neighbouring analogue channels. Therefore, for best results, the user should avoid inputting pulses to 'PULSE INPUT' during the data capture phase of transient recorder programs. When the channel gain is switched to give +/-250 millivolts dynamic range, the digitization step of the analogue to digital converter corresponds to approximately 2 millivolts. The output from some sensors, eg thermocouples, will require a stage of voltage amplification before the signal can be entered into VELA.

In the data logging programs (02 and 03) the analogue channels are sequentially selected in the order 1, 2, 3 and 4 by the analogue switch and the voltage is inputted to the Ferranti ZN448 ADC. The ADC's clock runs at f = 1 MHz, and therefore the digitization process takes approximately 9 microseconds. However, in order to pick up the 8 bit code and store it in the next memory location and check for the end of memory, the shortest period between two consecutive samples is 34 microseconds. This is the intersampling time when the VELA is data logging with program '01' and parameter '0'.

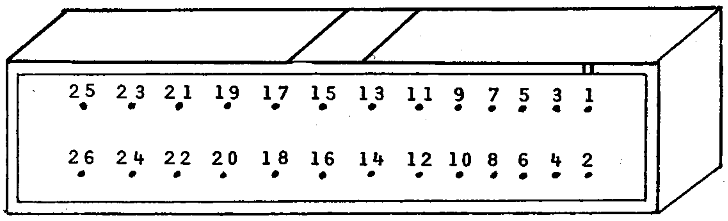
Although the analogue inputs are buffered, the digital input/output port is not buffered. These inputs and outputs are TTL compatible and as such could interface directly with microcomputer 'user ports' or printer input ports. If it is intended to use the digital lines to drive relays or lamps or motors, a power driver stage will be required, (eg Darlington drivers, ULN2001). The digital input/output port pin description and pin identification is shown in Table 5 and Figure 6.

A more complete description of the function of the PIA data lines and the control lines is given in Table 4. When power is applied to the VELA, the CP

| PIN | DESCRIPTION | PIN | DESCRIPTION |
|---|---|---|---|
| 1 | EARTH | 14 | PB0 DATA In/Out |
| 2 | EARTH | 15 | PA7 DATA In/Out |
| 3 | +5 volts | 16 | PA6 DATA In/Out |
| 4 | EARTH | 17 | PA5 DATA In/Out |
| 5 | CB2 ($E003) Control In/Out | 18 | PA4 DATA In/Out |
| 6 | CB1 ($E003) Control In/Out | | 19 PA3 DATA In/Out |
| 7 | PB7 DATA In/Out | 20 | PA2 DATA In/Out |
| 8 | PB6 DATA In/Out | 21 | PA1 DATA In/Out |
| 9 | PB5 DATA In/Out | 22 | CA2 ($E002) Control In/Out |
| 10 | PB4 DATA In/Out | 23 | PA0 DATA In/Out |
| 11 | PB3 DATA In/Out | 24 | CA1 ($E002) Control Input |
| 12 | PB2 DATA In/Out | 25 | EARTH |
| 13 | PB1 DATA In/Out | 26 | CA1 ($C002) Control Input |

TABLE 5

Note position of polarising keyway:




VIEW OF SOCKET FROM SIDE

FIGURE 6: DIGITAL INPUT/OUTPUT PORT

Although the PIA data lines shown in Table 5 could be programmed as either inputs or outputs, the convention adopted in the first seventeen programs is to assign PBO-PB7 as output lines and PAO-PA7 as input lines. Therefore the voltage measured on line PBO corresponds to the status of the least significant bit of the code stored in memory location $E001 and the voltage on line PB7 corresponds to the status of the most significant bit of the code stored in $E001. Similarly, the external voltage (+5 volts or 0 volts) applied to the line PAO will determine the status of the least significant bit of the code in $E000 and the external voltage applied to the line PA7 will determine the status of the most significant bit in $E000.

The eight digit 7 segment displays are controlled by an Intersil ICM7218CIJI CMOS Universal LED Driver integrated circuit. Included in this device is an 8 x 8 static memory array providing storage for the displayed information and all of the multiplex scan circuitry (to minimize the power drain) and the high power digit and segment drivers. The display driver is controlled by the PIA at $C000.

Most of the keys are scanned by the 74C922 keypad encoder but for historical reasons, four of the keys when pressed define a low voltage on one of four PIA data lines ($C000). The four keys in question are:

START    STOP    MICRO    and    <<>>

2.3 Software Expansion

Your only reason for opening up the VELA should be to extend the on-board software, as it becomes available, by inserting extra 2732 EPROM's into the sockets provided (IC23, IC24 and IC25). CARE must be exercised when disengaging the VELA box top from the base, and the following procedure is recommended:

i) Make sure that the power lead is disconnected.
ii) Remove the screws on the base of the VELA.

iii) On removing the base you will see the row of sockets next to the EPROM labelled ISL1* (green star).
iv) Read the instructions sent with the EPROM. The EPROM must be a type 2732 and must be inserted in the correct socket, the correct way round - as shown in figure 7.

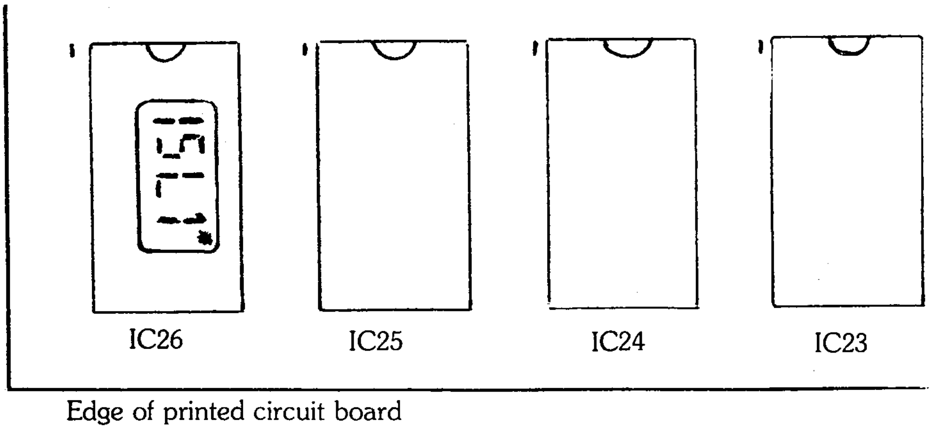



FIGURE 7: EPROM ORIENTATION

v) Do a quick visual check to ensure that all of the EPROM pins are seated in the socket holes and press down on the EPROM to make sure that it is held firmly by the socket.
vi) Reassemble the VELA.
The original 4096 bytes of software may therefore be extended by a further 12,288 bytes of software. An EPROM in socket IC23 can consist of a further 23 programs which can be called by the two digit program number 17dec through to 39dec inclusive. The EPROM in socket IC24 will be capable of providing a further 20 programs called by the two digit program numbers 40dec through to 59dec. It was always intended that a user, having tested a program in RAM (as described in Section 4) and having EPROM creation facilities, should be able to insert his own EPROM into socket IC24. The CPU expects to find the vector address of the start of the user routine at specific locations within the EPROM memory space. The range of locations assigned to the vector addresses is $AF50 - $AF77 inclusive. Let's take a specific example: if the user wants to start this routine at the lowest EPROM address $A000 and to call up this program with the two digit number 40, the user MUST place the most significant byte of the vector address ($A0) in memory location $AF50 and the least significant byte of the vector address ($00) in memory location $AF51. Similarly, if the user designates a routine starting at $A123 as program '41', the user MUST place $A1 in memory location $AF52 and $23 in memory location $AF53.

**3 Transfer Data to Microcomputer**

The VELA is essentially a stand alone device, but many of the programs become even more effective if the user has either an oscilloscope or a microcomputer system readily available. The transfer of data to the oscilloscope is a trivial task, involving the repetitive readout of a block of the VELA's RAM memory, and a synchronising pulse coincident with the start of each memory block readout, to facilitate a steady oscilloscope trace.

Data is transferred between microcomputer and peripheral devices either via a serial link or a parallel link. The technique adopted here is to use a parallel link where each bit of an 8 bit code defines the voltage on one of 8 data lines and the sender (VELA) keeps in synchronism with the receiver (a microcomputer) by means of two control lines. One of the control lines is energised by the sender just after a valid 8 bit code has been placed on the data lines. This pulse from the sender alerts the receiver to the fact that the correct code is on the data lines. The receiver then reads the data, stores it and energises the other control line with a positive voltage pulse. When the sender detects this pulse, it knows that the previous data code has been picked up and it can now replace the previous data code by the next valid code. The cycle is then repeated, as shown in figures 8(a). The transfer of data in this way is called a 'Handshake', and the receiver must have a special linker routine at the start of its data processing program in order to synchronise its operation with the VELA. (Examples of linker routines are shown in section 3.4, 3.5 and 3.6). The manufacturers can supply cables to most popular microcomputers.

A number of BASIC linker routines for popular microcomputers are given later in this text. The manufacturer can supply fast, machine code data transfer, plotting and analysis software for many microcomputers.

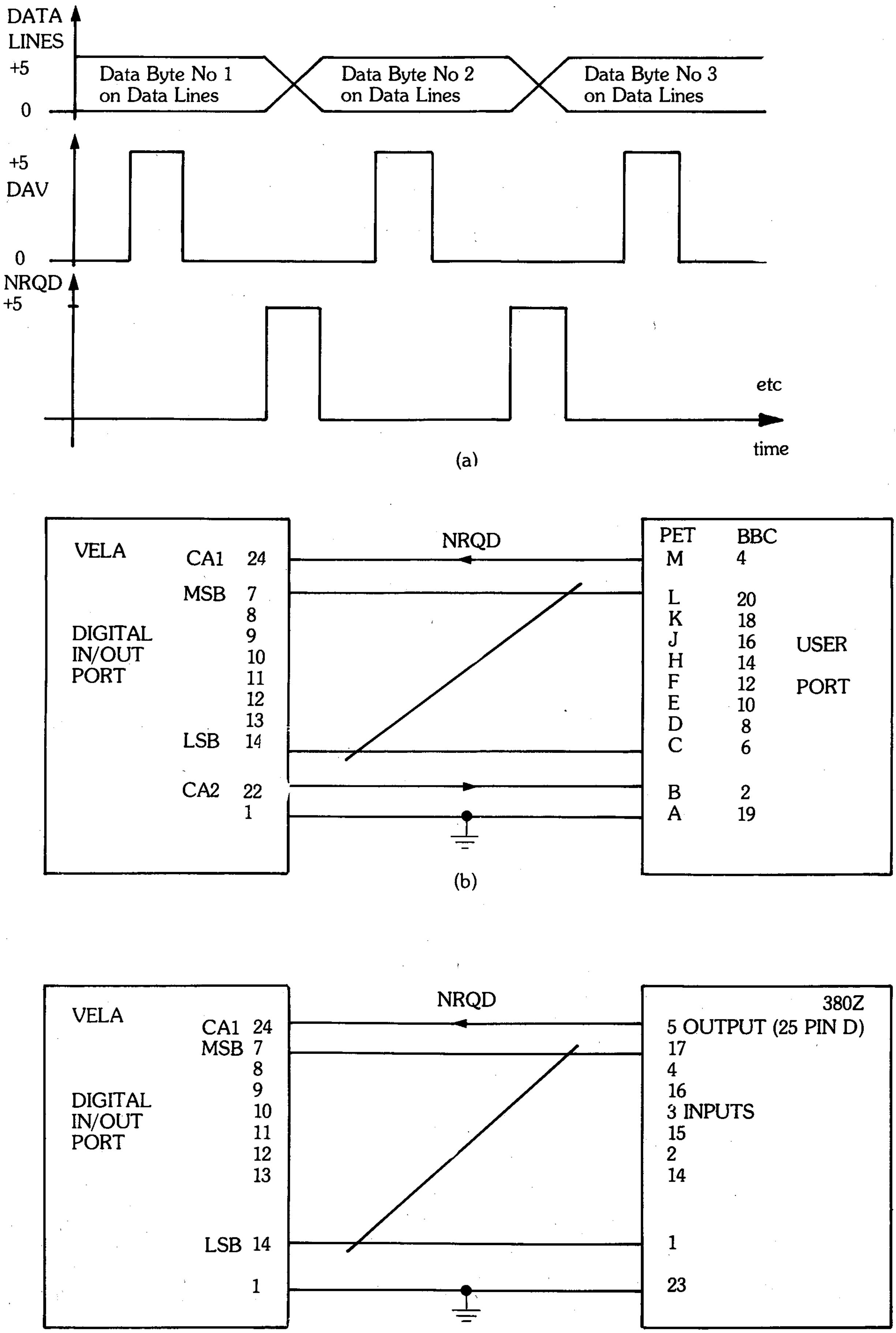



FIGURE 8: HANDSHAKING DATA BETWEEN VELA AND MICROCOMPUTERS

In theory, any microcomputer with eight data lines which can be defined as inputs and one (but preferably two) control lines can be linked to the VELA. Three common microcomputers are the Apple, Commodore machines and the BBC microcomputer. These machines can be connected to the VELA digital input/output port via their 'USER PORTS' as shown in figure 8(b). The manufacturers can supply a suitable user port card for the Apple. Note that no interface chips are required because all lines are TTL compatible. (However, if line drivers are not used, the cable between VELA and the microcomputer should be as short as is convenient). The Research Machiens 380Z is slightly different because it does not have any specific control lines. The 380Z has 8 input lines and 8 output lines, therefore the technique required is as shown in figure 8(c) where one of the 8 output lines has been assigned the "request new data" control line.

The procedure for transferring data from VELA to the PET or BBC machine would be:

i) RUN THE APPROPRIATE VELA PROGRAM
ii) RUN THE PET/BBC LINKER PROGRAM
iii) WAIT FOR END OF DATA LOGGING
iv) SELECT CHANNEL NUMBER 1, 2, 3 OR 4
v) PRESS 'MICRO' TO INITIATE DATA TRANSFER
vi) WHEN TRANSFER COMPLETED, VELA IS IN STANDBY OUTPUT MODE.

The procedure for transferring data from VELA to the 380Z must be slightly different, because there is no data valid control line to tell the 380Z when to read the 8 bit data code:

i) RUN THE APPROPRIATE VELA PROGRAM
ii) WAIT FOR END OF DATA LOGGING
iii) SELECT CHANNEL NUMBER 1, 2, 3 OR 4
iv) PRESS 'MICRO'
v) PRESS 'RUN' ON 380Z TO INITIATE READING OF FIRST 8 BIT CODE AND SENDING OF FIRST REQUEST FOR NEW DATA.

The linker program in the 380Z must wait for a sufficiently long time between sending the NRQD pulse and reading the next byte of data to be sure that the VELA has had time to respond and the data on the output lines has settled.

### 3.1 Handshake Protocol

When a block of data is transferred to a microcomputer, the 'receiving' microcomputer must not only have the simple 'linker' routine to coordinate the transfer, but there must be an agreed protocol within the data bytes. The size of the block of data depends upon the VELA program selected, therefore, the VELA must somehow tell the receiving microcomputer how many data bytes are to be transferred on the parallel link. Also, in order to file and process the data received, the microcomputer must know:

i) which VELA program generated the data ii) which parameter was chosen
iii) which channel or block was selected for readout (1, 2, 3 or 4) iv) the gain setting of the manual switch (when appropriate).

The protocol adopted for the data transfer is therefore

| NH | NL | PR | PARH | PARL | BLOCK | GAIN | FIRST DATA BYTE | SECOND DATA BYTE |
|---|---|---|---|---|---|---|---|---|

time →

where NH is the value of the first byte transferred, NL is the second byte transferred, etc.

The number of data bytes in the record is (256NH + NL) which must be differentiated from the total number of bytes transferred ie (256NH + NL + 7). The third byte transferred is PR and this represents the VELA program number selected. The fourth and fifth bytes transferred, PARH and PARL are the high and low byte of the parameter selected. Therefore the parameter value is given by (256PARH + PARL). The sixth byte called BLOCK contains 1, 2, 3 or 4 and represents either the analogue channel whose data values are to follow or a particular block of data (see 3.3). In the case of the satistics of Random Events programs (07, 08 and 09) 'BLOCK' defaults to the value 1. The seventh byte is necessary to define the gain setting during the TRANSIENT RECORDER programs - see below.

### 3.2 Data Formats

The structure of the data transferred depends upon the VELA program number selected.

1) TRANSIENT RECORDER (01, 02 AND 03)

After the 7 data byte preamble, the data bytes are outputted sequentially and in blocks of 1023dec bytes.

Note that the data transferred is in the form of an 8 bit code which defines a certain voltage value sensed by the ADC. The seventh byte transferred notifies the receiving microcomputer of the channel gain, G, during data-logging, and is either set 1, 10dec or 100dec, depending upon the chosen dynamic range of +/-0.25 volts, ;/-2.5 volts or +/-25.0 volts. The conversion from transferred data value to volts seen at the input is therefore given by

$$\text{volts} = 0.25^* \, (\text{data dec} - 128)^* \, \frac{G}{128}$$

ii) MULTICHANNEL TIME (06)

After the 7 byte preamble, the data bytes are organised in the following way:

| | | | | | |
|---|---|---|---|---|---|
| FIRST CODE SEEN | 0 | 0 | SECOND CODE SEEN | $T_H$ | $T_L$ |

time ⟶

The data bytes come in sets of three bytes; the first byte is the 8 bit code corresponding to the voltages on each of the 8 input data lines (at $E000) and the next two bytes contain TH, the most significant byte and TL, the least significant byte of the time in milliseconds, Tm when the previous 8 bit code had been detected.

$T_m = 256\ T_H + T_L$ milliseconds.

As an example of a simple routine to decode this data format, the following program may be added to the PET linker routine (see section 3.4). The program was developed for an airtrack demonstration in which 8 optical sensors were connected to the 8 input data lines.

```
50    IF PROG <>6 THEN GO TO 95
51    NUM = (NMX - 7)/3
52    DIM T% (NUM): DIM CODE%(NUM)
54    FOR N = 1 TO NUM : CODE%(NUM) =PEEK(24325 + 3*N)
56    T%(N) = PEEK(2432 + 3*N*)*256 + PEEK(24327 + 3*N)
57    NEXT
58    PRINT " "
65    PRINT "*** AIRTRACK EXPT ***"
66    PRINT ""
67    PRINT "... VELA PROGRAM 06 ...": PRINT ""
68    PRINT "... CODES ... TIMES"
69    FOR N = 1 TO NUM
71    IF T%(N) <> 0 THEN GO TO 75
73    PRINT "0.000", "SECS"
74    GO TO 95
75    PRINT CODE%(N), "SECS"
80    NEXT
95    END
```

iii) STATISTICS OF RANDOM EVENTS (07, 08, 09)

After the 7 byte preamble, the data is outputted sequentially in a 256dec block, starting with $8000. The true data set starts at $8001 and therefore the first data byte should be ignored.

### 3.3 Transfer Data to Microcomputer (Program 15)

It was decided to provide a separate program for the transfer of data to the microcomputer so that, for example, a user creation program that had been developed and tested in RAM could be saved on a microcomputer for future reference. This program is also used when VELA has been used for data capture in the field and data is then transferred from battery protected RAM into the computer.

The procedure to be followed is given below:

a) Press [RESET] to display the program prompt 'P-'
b) Select [1] [5] and then a parameter value betwen 0 and 999 and [ENTER]. (The display will go blank)
c) Select the block number [CH1], [CH2], [CH3] or [CH4]
d) Make sure that the receiver is running the "linker routine"
e) Press [MICRO] key

The parameter value can be regarded as a file number which allows the user to store and identify up to 1000 different data sets if necessary.

The channel number chosen determines which 1024dec bytes of memory will be transferred as shown in the table 6 below:

| PROGRAM 15 CHANNEL SELECT | MEMORY BLOCK SELECTED HEXADECIMAL | DECIMAL |
|---|---|---|
| CH 1 | $8000 → $83FF | 32,768 → 33,791 |
| CH 2 | $8400 → $87FF | 33,792 → 34,815 |
| CH 3 | $8800 → $8BFF | 34,816 → 35,839 |
| CH 4 | $8C00 → $8FFF | 35,840 → 36,863 |

TABLE 6

## 3.4 Transfer Data from VELA to Commodore PET

COMMODORE PET LINKER ROUTINES

```
1    ?"[♥]" ;?"**** TRANSFER DATA FROM VELA TO PET ****":?""
2    ?" - - WHEN READY PRESS MICRO KEY ON VELA - -"
3    N = 0
4    DIM A%(2)
5    POKE 59459,0
8    POKE 59468, PEEK (59468) OR 225
9    POKE 135,95: POKE 134,0
10   POKE 59468, PEEK (59468) AND 223
12   K = PEEK (59457)
13   A%(1) = 0:A%(2) = 0
15   WAIT 59469,2
20   K = PEEK (59457)
21   MEM=24320+N:N=N+1
22   X=PEEK (59471)
24   X$ = RIGHT $ ("....." + STR$(X),4)
26   PRINT X$;
27   IF N <> 1 THEN GO TO 29
28   A%(1)=X*256
29   IF N <> 2 THEN GO TO 31
30   A%(2) = X
31   POKE MEM,X
34   POKE 59468, PEEK (59468) OR 225
35   POKE 59468, PEEK (59468) AND 223
37   NMX = A%(1) +A%(2) + 7
40   IF N <> NMX THEN GO TO 15
45   PROG = PEEK (24323)
46   PAR = 256 * PEEK (24324) + PEEK (24325)
47   CH = PEEK (24326)
50   END
```

This linker routine gives visual confirmation that the data transfer from the VELA to the PET taking place because each data code is written onto the PET screen. The data codes are placed into the PET memory addresses 24320dec and above. The important variables are as follows:

| | |
|---|---|
| NMX | Total number of data codes transferred |
| PROG | The VELA program number |
| PAR | The parameter value (0-999) |
| CH | The channel number. |

If the transient recorder routines have outputted data, the channel gain data byte, GAIN can be picked up by

```
48        GAIN = PEEK(24327)
```

- see Section 3.2 for conversion to volts expression.

### 3.5 Transfer Data from Vela to BBC Microcomputer

BBC MICROCOMPUTER LINKER ROUTINE

```
100   REM *** SET GRAPHICS MODE REQ & RESERVE SPACE FOR 1K DATA ***
102   MODE 1 : HIMEM = HIMEM - &401
105   DIM AD%(7) : MPOS%=HIMEM + 1
110   REM *** DEFINE BBC VIA REGISTERS ***
115   PCR = &FE6C: IER = &FE6E : NIFR = &FE6D : DDRB = &FE62 = : DTAB = &FE60
120   REM *** SET UP PORT B - ALL INPUTS ***
121   ?DDRB = 0
122   REM *** CLEAR INTERRUPT ENABLE REGISTER ***
123   ?IER = 0
124   REM *** CLEAR INTERRUPT REGISTER ***
125   ?NIFR=&FF
126   REM *** SET UP CB1 RISING EDGE IRQ, CB2 MANUAL DATA TAKEN PULSE ***
127   ?PCR=&D0
140   REM *** CLEAR SCREEN ***
150   CLS
153   REM *** PICKOUT 7 PREAMBLE BYTES ***
155   FOR N% = 1 TO 7
158   REM *** WAIT FOR DATA READY ***
160   DR% = ?NIFR : IF DR% = 0 THEN 160
170   REM *** CLEAR INTERRUPT REGISTER ***
175   ?NIFR = &FF
180   REM *** GET DATA BYTE ***
182    AD%(N%) = ?DTAB
185   REM *** SEND DATA TAKEN PULSE ***
187   ?PCR = &F0 : ?PCR = &D0
190   NEXT N%
192   REM *** CALCULATE No OF DATA BYTES ***
195   NB% = AD%(1)*256 + AD%(2)
200   FR% = 0 : FOR N% = 1 TO NB%: IF FR% <> 0 THEN 210
205   VL$ = RIGHT$("    " +STR$(N%),4):PRINT VL$;"    ";
210   DR% = ?NIFR : IF DR% = 0 THEN 210
220   ?NIFR = &FF
225   REM *** GET DATA BYTE AND STORE IN MEMORY ***
230   DB% = ?DTAB : ?MPOS% = DB%
235   DB$ = RIGHT$("   " + STR$(DB%),3)
240   ?PCR = &F0 : ? PCR = &D0
250   MPOS% = MPOS% + 1 : PRINT DB$; "    ";
255   FR% = FR% + 1 : IF FR% <> 4 THEN 280
258   REM *** STOP ONLY IF KEY PRESSED ***
260   PRINT : FR% = 0: IF INKEY(10) = -1 THEN 280
270   FOR J% = 1 TO 100 : NEXT J%
273   REM *** WAIT FOR 2nd KEY PRESS TO CONTINUE ***
275   IF INKEY(10) = -1 THEN 275
280   NEXT N%
285   PRINT : PRINT
290   PRINT "NUMBER OF DATA BYTES =";NB%
295   PRINT : PRINT "PROGRAM NUMBER";AD%(3)
300   PRINT : PRINT "PARAMETER VALUE";AD%(4)*256 +AD%(5)
305   PRINT : PRINT "DATA BLOCK NUMBER";AD%(6)
306   PRINT : PRINT "CHANNEL GAIN";AD%(7)
```

(See Section 3.2 for conversion to volts expression)

### 3.6 Transfer Data from VELA to RML 380Z

RML 380Z LINKER ROUTINE

```
100 REM *** PREPARE A 1K BUFFER ABOVE 'BASIC' FOR DATA ***
105 CLEAR 200,, 1024
110 REM *** SET POINTER TO START OF BUFFER ***
115 MP = PEEK (& 11C) + PEEK (& 11D) * 256 + 1 : SP = MP
120 REM *** USER PORT ON 380Z = & FBFF ***
125 IP = 0 : 0P = 0: PT = & FBFF
130 REM *** CLEAR SCREEN ***
135 PRINT CHR$(12)
140 REM *** PREVENT 'BASIC' FROM INHIBITING SCROLLING ***
145 PRINT CHR$(17)
150 REM *** GET FIRST 7 PREAMBLE BYTES ***
155 FOR J = 1 TO 7
160 BT = PEEK (PT) : A(J) = BT
170 REM *** PULSE DATA TAKEN LINE ***
175 POKE PT, 1: POKE PT, 0
180 REM *** CALCULATE No OF DATA BYTES ***
185 NEXT J : NB = A(1) *256 + A(2)
190 FR = 0 : FOR J = 1 TO NB : IF FR <> 0 THEN 210
200 VL$ = RIGHT$("     " + STR$(J),4) : PRINT VL$; "   ";
205 REM *** GET BYTE AND STORE IN MEMORY ***
210 BT = PEEK (PT) : POKE PT, 1 : POKE PT, 0
220 POKE MP, BT : MP = MP + 1
230 REM *** OUTPUT TO SCREEN (BYTE No & 4 DATA BYTES ACROSS) ***
240 BT$ = RIGHT$("     " + STR $ (BT),3): PRINT BT$; "   ";
245 FR = FR + 1 : IF FR < 4 THEN 280
250 REM *** STOP SCROLLING IF KEY PRESSED ****
255 PRINT: FR = 0 : CH = GET(10) : IF CH = 0 THEN 280
260 FOR K = 1 TO 100 : NEXT K
270 REM *** WAIT FOR 2nd KEYPRESS TO CONTINUE ***
275 CH = GET (10): IF CH = 0 THEN 275
280 NEXT J
```

This linker routine gives visual confirmation that the data transfer from VELA to 380Z is taking place because each data code is written onto the 380Z screen. The routine has been tested using RML 'BASICS' V5.0 and should run under 'BASICS G' and 'BASICS G2' (V5.0) without trouble.

The important variables are as follows:

| | |
|---|---|
| NB | The number of data bytes |
| A(3) | The VELA program number |
| A(6) | The channel (or block) number |
| A(7) | The channel gain value (see page 19) |

Note, that to reconstruct the parameter value (0 → 999dec), a line could be inserted in the linker

188 PAR = A(4)*256+A(5)

where PAR is the appropriate parameter.

### 3.7 Transfer Data from VELA to Apple

This routine is designed to be used in conjunction with the manufacturers' Apple User Port card.

APPLE LINKER ROUTINE

```
10   DIM A(7)
100  REM *** SEARCH FOR CARD ***
110  BASE = 49280:SLOT = 0
120  FOR LOOP = 1 TO 5
130  X = PEEK (BASE + LOOP * 16)
140  Y = PEEK (BASE + 1 + LOOP * 16)
150  IF X=69 AND Y=69 THEN SLOT=LOOP: LOOP = 5
160  NEXT LOOP
170  IF SLOT = 0 THEN PRINT "CARD NOT FOUND":END
180  PRINT "CARD IN SLOT";SLOT
190  DPRT = BASE + SLOT * 16 + 2
195  POKE DPRT,255
200  REM *** RESERVE 1K SPACE ***
210  POKE 116, PEEK (116) - 4
220  TP = PEEK (116) * 256 + PEEK (115)
260  CALL - 936: VTAB 10: HTAB 8: PRINT "START TRANSFER ON VELA"
270  VTAB 12: HTAB 10: PRINT "THEN PRESS ANY KEY"
280  GET A$: IF A$ = "" THEN GOTO 280
290  CALL - 936: REM *** CLEAR SCREEN ***
300  REM *** READ 7 PARAMETER BYTES ***
310  FOR LOOP = 1 TO 7
320  A(LOOP) = PEEK(DPRT)
330  POKE DPRT,0: POKE DPRT,255
350  NEXT LOOP
360  REM *** CALCULATE NO. OF DATA BYTES ***
370  BYTE = A(1) * 256 + A(2)
380  PRINT "NUMBER OF BYTES";BYTE
400  REM *** READ DATA FROM VELA ***
420  FOR LOOP = 0 TO BYTE
415  IF RC = 0 THEN PRINT RIGHT$ ("    " + STR$(LOOP),4);"    ";
420  DT = PEEK (DPRT)
425  POKE DPRT,0: POKE DPRT,255
430  POKE TP + LOOP,DT
440  PRINT RIGHT$("      " + STR$(DT),6);
450  RC = RC + 1: IF RC = 4 THEN RC = 0: PRINT
470  NEXT LOOP
480  PRINT "TRANSFER COMPLETE"
485  PRINT "BUFFER STARTS AT ";TP
490  PRINT "TO OVERWRITE BUFFER GOTO260"
500  PRINT "TO FILL NEXT BUFFER RUN"
```

### 3.8 Transfer Data from VELA to Commodore 64

COMMODORE 64 LINKER ROUTINE

```
100   REM *** INITIALISE PORTS AND DATA BUFFER POINTER ***
105   APRT=56576:BPRT=56577:ADDR=56578:BDDR=56579
106   FLAG=56589:BUF=49401:MPTR=BUF+6
110   POKE ADDR,PEEK(ADDR)OR4:POKE BDDR,0:POKE APRT,PEEK(APRT) AND 251
      :Q=PEEK(FLAG)
120   PRINT "[CLR 5 x CD]"; TAB(8)"SELECT CHANNEL ON 'VELA' ":PRINT
130   PRINTTAB(16);"WAITING"
135   REM *** WAIT FOR 'DATA AVAILABLE' SIGNAL FROM 'VELA' ***
140   IF PEEK(FLAG)AND16 THEN 200 :
150   T=TIME
160   IF TIME - T< 20 THEN 160
170   T=TIME:PRINT"[CU 32 × SPACE]"
180   IF TIME - T< 20 THEN 180
190   PRINT "[CU]"; :GOTO 130
195   REM *** GET 7 PARAMETER BYTES FROM 'VELA' ***
200   FOR J=0 TO 6:A%(J)=PEEK(BPRT) :POKE BUF+J,A%(J):POKE APRT, PEEK(APRT)OR4
205   POKE APRT,PEEK(APRT)AND 251
210   IF (PEEK(FLAG)AND 16)=0 THEN 210
220   NEXT
230   REM *** CALCULATE NUMBER OF DATA POINTS TO TRANSFER ***
240   NPTS = A%(0) * 256 + A%(1)
270   REM *** LOOP TO TRANSFER 'NPTS' FROM 'VELA' ***
280   REM *** STORING DATA IN BUFFER AND DISPLAYING ***
290   REM *** VALUES ON SCREEN IN COLUMNS OF FOUR ***
300   PRINT "[CU]":PRINT" 1 : "; :FOR J=1 TO NPTS:VL%=PEEK(BPRT)
310   POKE MPTR+J,VL%:POKE APRT, PEEK(APRT)OR4:POKE APRT,PEEK(APRT)AND 251
320   VL$=RIGHT$("    " +STR$(VL%),4)+"    ":PRINTVL$
330   CT%=CT%+1:IF CT%=4 THEN PRINT RIGHT$("    " +STR$(J+1),4); "   :   ";:CT%=0
340   IF J=NPTS THEN PRINT:GOTO 360
350   IF (PEEK(FLAG)AND 16)=0 THEN 350
360   NEXT
400   PRINT "[CLR 5 x CD]"; TAB(12); "DATA TRANSFERRED"
410   PRINT "[3 x CD]"; TAB(6);" NO OF POINTS = ";STR$(NPTS)
420   PRINT:PRINT TAB(6); "DATA STORED AT ";STR$(MPTR)
430   PRINT:PRINT TAB(6); "PARAMETERS IN ARRAY A%( )"

READY
```

NOTES

In print statements in the above example where items inside quotes are enclosed inside square brackets, the user should not literally type the square brackets and characters enclosed, but should press the keys on the Commodore 64 keyboard as indicated below.

| | |
|---|---|
| [CLR] | = press 'shift' and 'clear/home' keys together. |
| [CU] | = press 'shift' and '↓' keys together. |
| [5 x CD] | = press '↓' key five times. |
| [32 x SPACE] | = press 'spacebar' 32 times. |

## 4 USER PROGRAM CREATION (Program 16)

The manufacturers can supply a complete "VELA Applications" Manual giving details of the existing routines in VELA, an explanation of their functioning, and invaluable guidance on user program creation and application.

The most elementary type of program is a sequence of 8 bit codes. This is called a machine code program. The decimal equivalent of each 8 bit code is a number between 0 and 255dec. As the VELA can only accept decimal data via the keypad(1) the User Program is composed of a set of decimal numbers in consecutive memory locations. The first program instruction code MUST be placed at the displayed memory address '1' and the maximum number of program codes is 1023dec.

In order to create one's own program, the VELA program number '16' must be entered (no parameter is necessary at this stage)(2). The display goes momentarily blank and then the memory location 1 appears in the centre of the display and the contents of that location appears on the right hand side of the display. If the code in the memory location is the correct one, press '>' to move onto the next location. If a new code is required at this memory location, simply type in the new code and press ENTER. The display momentarily flickers when the new code replaces the old code in that memory location. (If you make a mistake while typing the code, press ENTER and then retype in the correct code and ENTER again.) The user can now press '>' to move onto the next memory location or '<' to check the previous memory location's contents. In this way, the sequence of decimal equivalent codes can be defined.

Note that if a decimal code greater than 255 is entered, the VELA will place '1' in that memory location. The user program will be executed as soon as the START button is depressed, and if for some reason you want to stop your program, the only way is to press RESET. Your program may then be altered or checked out using the TRACE facility (see section 4.2), requesting program 16 again and pressing ENTER.

An example of a nontrivial program which is easily created by the user is shown in figure 10. This program generates a triangular waveform whose frequency is approximately 55 Hz. The program uses one of the subroutines in the on board EPROM in order to output an analogue voltage to the oscilloscope. The addresses of other useful routines are shown in table 8.

The CPU inside the VELA is the Motorola 6802 and there are a number of special registers within the CPU which do not have an assigned memory location. These registers are shown in figure 9.

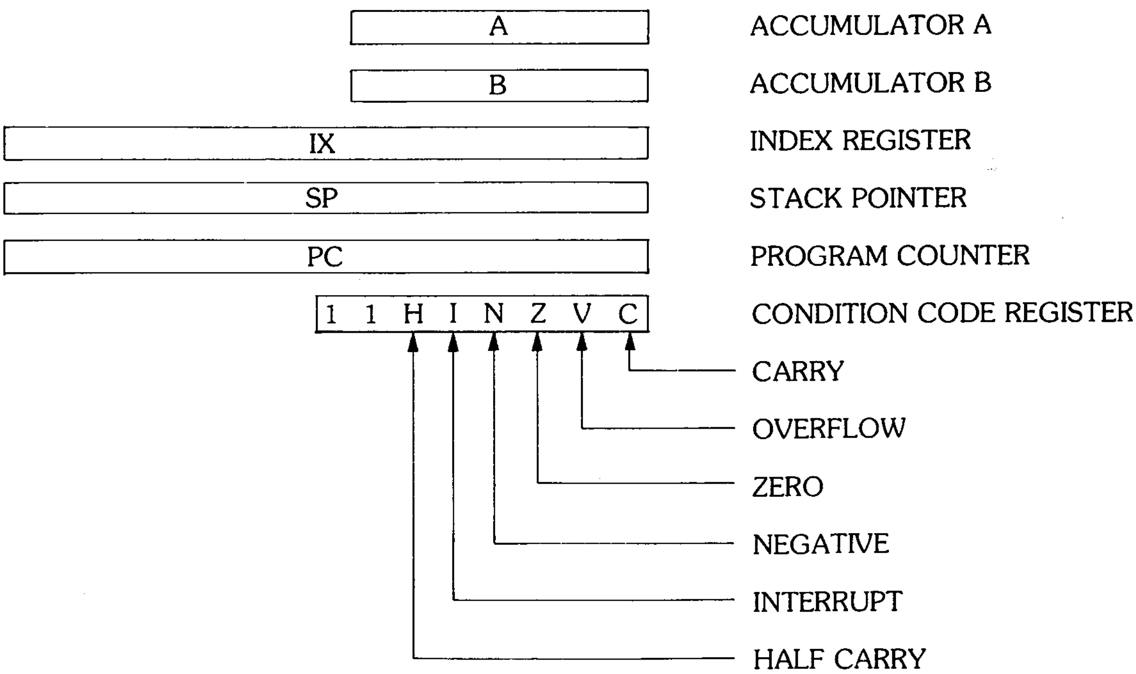



FIGURE 9: 6802 CPU REGISTERS

(1) & (2) See notes overleaf

(1) There exists a routine in an additional EPROM which could allow a user creation program to be entered in hexadecimal codes (and which displays the hexadecimal addresses).
(2) If program number '16' is followed by a parameter $n_1n_2n_3$, VELA assumes that the user wishes to jump to memory location $n_1n_2n_3$ of the machine code program in order to verify (and possibly change) the code at that location.

Most of the arithmetical and logical operations are performed in the 8 bit registers A and B. Therefore, the CPU has to fetch data from the addressable memory locations and place the data into these special registers so that the data can be processed and then returned to external memory locations. Although there are a relatively small number of distinct operations that the CPU can perform, there are many ways of acquiring data. The different ways of acquiring data are called addressing modes.

For example, the operation code for "load data into accumulator A" is either 134 or 150 or 166 or 182. If the code 134dec is followed by the code 18dec, this instructs the CPU to load accumulator A with the data value 18dec. If however, the code 150dec is followed by 18dec, this would instruct the CPU to load accumulator A with the data in memory location $0012 (which is the 18th address in the micro's memory space.) If the code 166dec is followed by 18dec, the CPU would fetch data from a memory location whose address was the eighteenth after the address specified by the contents of the index register. Finally, if the code 182dec were used, it would have to be followed by two codes and these two codes would specify the memory address from which to fetch data. (Note that in Motorola machine code, the most siginificant byte preceeds the least significant byte.) The decimal equivalent codes representing the total number of operations and their respective addressing modes allowed are tabulated in the Motorola 6802 Instruction Set in figures 12, 13 and 14.

The program counter is a 16 bit register which keeps track of the memory address of the next executable instruction in the program which is being run.

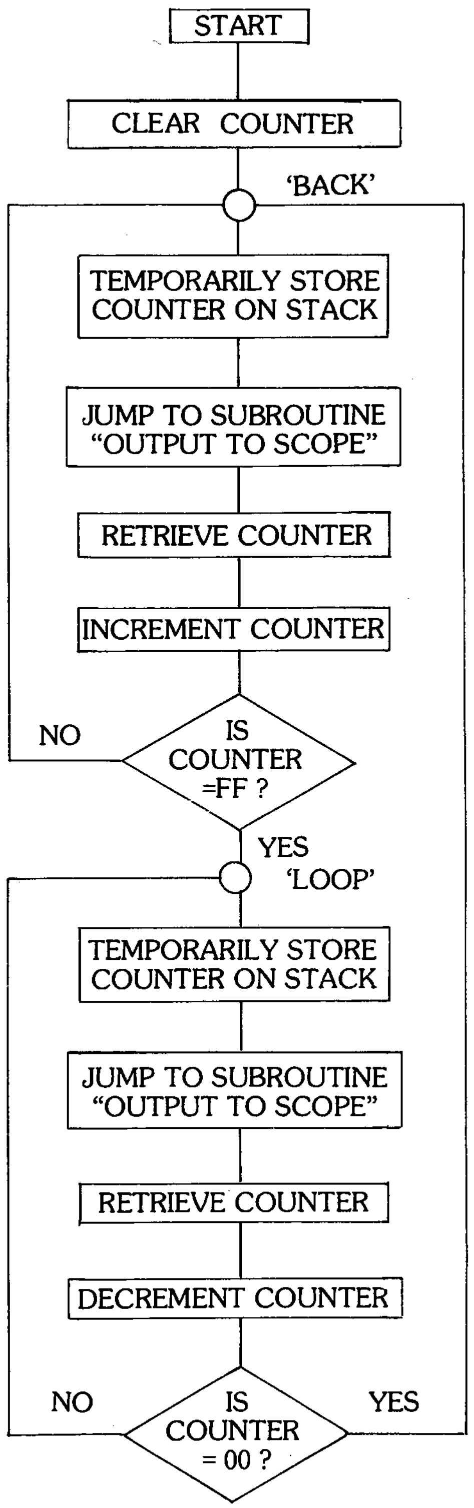
The stack point is a 16 bit register which keeps track of the location in the stack area of memory where data can be temporarily stored.

The index register is a 16 bit register which can be used either as a countup or countdown register.

The condition code register is an 8 bit register whose two most significant bits are always '1' and whose remaining six bits are independent flags which are set or cleared depending on the instruction being performed. There are many branch instructions (see figure 14) which can be used to alter the program counter (and hence the program flow) on the basis of one or more of these flags being set. The programmer may want the CPU to branch forwards OR backwards. The convention followed by Motorola is that if the most significant bit of the code following the branch opcode is '0', this code will represent a branch FORWARD. Therefore the maximum number of steps foward is 127dec. If the most significant bit of the code following the branch opcode is '1', this code will represent a branch BACKWARD. In table 9, the decimal codes required for both forward (+ve) and backward (-ve) branches are tabulated, eg if you want to BRANCH ALWAYS BACKWARDS BY 35 STEPS, look up the code for BRANCH ALWAYS, ie 32dec and the code for -35, ie 221dec and therefore the coded instruction becomes 32,221. Another reason for table 9 is that assembly language programmers are used to hexadecimal codes and for certain instructions, a ready reckoner from hexadecimal to decimal is desirble. For example, if the JUMP instruction is used, it must be followed by the complete address where the CPU is to jump to. If we wanted JUMP TO ADDRESS $8157, we would find the opcode for JUMP ie 126dec and the memory address would have to be split into the most significant byte $81 (129dec) and the least significant byte $57 (87dec). The instruction would therefore be coded as JUMP TO $8157 126, 129, 87.

The reader should refer to a Motorola Programming Manual for a complete description of the operation codes. Full details are also given in the "VELA Applications" manual mentioned at the start of this section.

## 4.1 USER PROGRAM PROJECT: TRIANGULAR WAVE OUTPUT TO OSCILLOSCOPE




| | Motorola Assembly Language | Memory Location | Decimal Codes Required |
|---|---|---|---|
| | CLRA | 1 | 79 |
| 'BACK' | PSHA | 2 | 54 |
| | JSR $FE33 | 3,4,5 | 189,254,51 |
| | PULA | 6 | 50 |
| | INCA | 7 | 76 |
| | CMPA£FF | 8,9 | 129,255 |
| | BNE'BACK' | 10,11 | 38,246 |
| 'LOOP' | PSHA | 12 | 54 |
| | JSR $FE33 | 13,14,15 | 189,254,51 |
| | PULA | 16 | 50 |
| | DECA | 17 | 74 |
| | BNE 'LOOP' | 18,19 | 38,248 |
| | BRA 'BACK' | 20,21 | 32,236 |

FIGURE 10: FLOWCHART AND CODES FOR USER PROJECT

PROCEDURE

(a) [RESET]
(b) CALL PROGRAMME NUMBER [1][6]
(c) ENTER
(d) REPLACE FIRST CODE BY PRESSING [7][9] AND [ENTER]
(e) PRESS [ > ] TO GAIN ACCESS TO NEXT MEMORY ADDRESS
(f) REPLACE NEXT CODE BY PRESSING [5][4] AND [ENTER]

and repeat for all 21 codes.

The output waveform generated by the program should have the appearance of figure 11 at the analogue output socket.

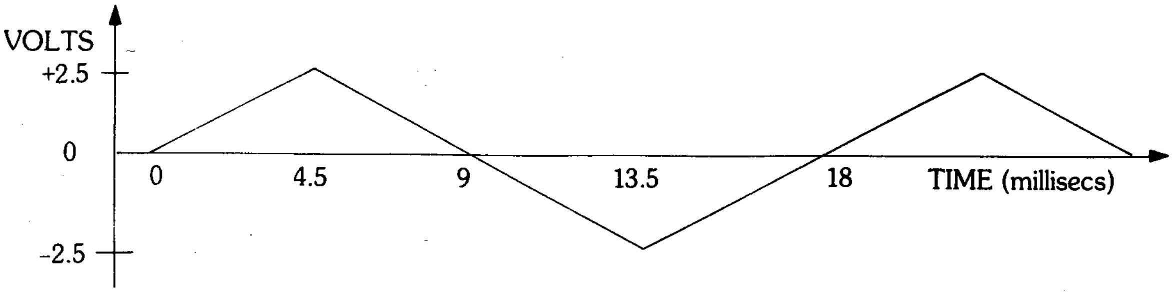



FIGURE 11: TRIANGULAR WAVE GENERATION

### 4.2 Trace Facility

During program development, it is essential to have the ability to halt the program at a certain point and to then interrogate the CPU registers in order to see if they have their expected values. An elementary 'trace' facility such as this has been provided on the VELA and it is entered whenever the CPU meets a software interrupt (SWI) code as the next executable instruction within the user's program. The decimal equivalent Motorola SWI code is 63dec.

When the CPU detects this code, it stores its registers in the 'stack', blanks the display and then displays the decimal value of the program counter (PC) when the SWI code was seen. Successive FWD keypresses will display the contents of the other CPU registers in the order shown in table 7.

| DISPLAY | RANGE OF VALUES |
|---|---|
| PROGRAM COUNTER | 35,841→36,863 |
| INDEX REGISTER | 0 → 65,535 |
| ACCUMULATOR A | 0 → 255 |
| ACCUMULATOR B | 0 → 255 |
| CONDITION CODE REGISTER | 11XXXXXX* |
| STACK POINTER | 80 → 123 |
| PROGRAM COUNTER | etc |

* X DENOTES 1 OR 0

TABLE 7

Note that all of the registers except the Condition Code Register have their contents displayed as a decimal value. However, each bit within the Condition Code Register represents a flag which is either set to '1' or cleared, depending upon the arithmetic result of the previous instruction executed by the CPU. Therefore, it is most useful to display the contents of this CCR as eight binary digits on the VELA.

The only way to escape from this continuous looping display of the CPU registers is to press RESET. The user program may then be re-entered by defining program number '16' and by stepping FWD through the program codes, the SWI code can be replaced by the next executable opcode.

| | SOME USEFUL SUBROUTINE MEMORY ADDRESSESS |
|---|---|
| $F041 | DISPLAY 'HELLO' |
| F176 | OUTPUT 5 DIGIT VALUE TO DISPLAY |
| F21A | DELAY FOR 500 MILLISECONDS |
| F225 | DISPLAY 'HI' |
| F27C | WAIT FOR 'START' PULSE |
| F287 | FIND AVERAGE OF 256 SAMPLES |
| F2A0 | MAKE AN ANALOGUE SAMPLE |
| F38E | DISPLAY 'LO' |
| F407 | OUTPUT MEMORY AND CONTENTS TO DISPLAY |
| F538 | OUTPUT 8 BITS OF ACCB ON DISPLAY |
| F62A | OUTPUT DAV PULSE |
| FCA5 | OUTPUT 1024dec BYTES TO OSCILLOSCOPE |
| F7D5 | MOVE BACKWARDS THROUGH MEMORY |
| F7F5 | MOVE FORWARDS THROUGH MEMORY |
| F609 | SELECT INPUT ANALOGUE CHANNEL |
| F10B | OUTPUT POSITIVE SYNC STEP |
| F9F9 | DELAY FOR 50 MILLISECONDS |
| FA22 | OUTPUT 256dec BYTES TO OSCILLOSCOPE |
| FA45 | CLEAR RAM $8000 — $80FF |
| FD72 | OUTPUT A SYNC PULSE |
| FDEE | CHECK FOR 1,2,3 OR 4 KEYPRESS |
| FE00 | TEST FOR KEYPRESS |
| FE19 | CLEAR ALL 4K RAM LOCATIONS |
| FE25 | BRING ON 'VOLTS' LED |
| FE29 | BRING ON 'SECS' LED |
| FE2D | BRING ON 'HERTZ' LED |
| FE33 | OUTPUT TO OSCILLOSCOPE |
| FE8E | CONVERT BINARY TO DECIMAL |
| FED1 | CONVERT DECIMAL TO BINARY |
| FF1C | BLANK THE DISPLAY |
| FFB8 | OUTPUT A CHARACTER |
| FF2A | INPUT '2 DIGIT PROG NUMBER' |
| FF52 | INPUT '3 DIGITS AND ENTER' |
| FFC5 | INPUT A CHARACTER |

TABLE 8

**4.3 Transfer User Program to Microcomputer**

The reader should refer to the notes in Section 3 and in particular to Section 3.3, because program '15' must be entered if a User Program is to be saved. User Creation Program codes are located at memory locations $8C01 and higher. Therefore, in order to save a user program on the microcomputer, the block number CH4 must be selected. (On the next EPROM, there will be 'DOWNLOADER' program which will allow the reloading of VELA programs saved on the microcomputer.)

| OPERATIONS | | IMMED OP ~ # | DIRECT OP ~ # | INDEX OP~ # | EXTND OP ~ # | IMPLIED OP ~ # |
|---|---|---|---|---|---|---|
| Add | ADDA | 139 2 2 | 155 3 2 | 171 5 2 | 187 4 3 | |
| | ADDB | 203 2 2 | 219 3 2 | 235 5 2 | 251 4 3 | |
| Add Acmltrs | ABA | | | | | 27 2 1 |
| Add with Carry | ADCA | 137 2 2 | 153 3 2 | 169 5 2 | 185 4 3 | |
| | ADCB | 201 2 2 | 217 3 2 | 233 5 2 | 249 4 3 | |
| And | ANDA | 132 2 2 | 148 3 2 | 164 5 2 | 180 4 3 | |
| | ANDB | 196 2 2 | 212 3 2 | 228 5 2 | 244 4 3 | |
| Bit Test | BITA | 133 2 2 | 149 3 2 | 165 5 2 | 181 4 3 | |
| | BITB | 197 2 2 | 213 3 2 | 229 5 2 | 245 4 3 | |
| Clear | CLR | | | 111 7 2 | 127 6 3 | |
| | CLRA | | | | | 79 2 1 |
| | CLRB | | | | | 95 2 1 |
| Compare | CMPA | 129 2 2 | 145 3 2 | 161 5 2 | 177 4 3 | |
| | CMPB | 193 2 2 | 209 3 2 | 225 5 2 | 241 4 3 | |
| Compare Acmltrs | CBA | | | | | 17 2 1 |
| Complement,1's | COM | | | 99 7 2 | 115 6 3 | |
| | COMA | | | | | 67 2 1 |
| | COMB | | | | | 83 2 1 |
| Complement,2's | NEG | | | 96 7 2 | 112 6 3 | |
| (Negate) | NEGA | | | | | 64 2 1 |
| | NEGB | | | | | 80 2 1 |
| Decimal Adjust, A | DAA | | | | | 25 2 1 |
| Decrement | DEC | | | 106 7 2 | 122 6 3 | |
| | DECA | | | | | 74 2 1 |
| | DECB | | | | | 90 2 1 |
| Exclusive OR | EORA | 136 2 2 | 152 3 2 | 168 5 2 | 184 4 3 | |
| | EORB | 200 2 2 | 216 3 2 | 232 5 2 | 248 4 3 | |
| Increment | INC | | | 108 7 2 | 124 6 3 | |
| | INCA | | | | | 76 2 1 |
| | INCB | | | | | 92 2 1 |
| Load Acmltr | LDAA | 134 2 2 | 150 3 2 | 166 5 2 | 182 4 3 | |
| | LDAB | 198 2 2 | 214 3 2 | 230 5 2 | 246 4 3 | |
| OR, inclusive | ORAA | 138 2 2 | 154 3 2 | 170 5 2 | 186 4 3 | |
| | ORAB | 202 2 2 | 218 3 2 | 234 5 2 | 250 4 3 | |
| Push Data | PSHA | | | | | 54 4 1 |
| | PSHB | | | | | 55 4 1 |
| Pull Data | PULA | | | | | 50 4 1 |
| | PULB | | | | | 51 4 1 |
| Rotate Left | ROL | | | 105 7 2 | 121 6 3 | |
| | ROLA | | | | | 73 2 1 |
| | ROLB | | | | | 89 2 1 |
| Rotate Right | ROR | | | 102 7 2 | 118 6 3 | |
| | RORA | | | | | 70 2 1 |
| | RORB | | | | | 86 2 1 |
| Shift Left, | ASL | | | 104 7 2 | 120 6 3 | |
| Arithmetic | ASLA | | | | | 72 2 1 |
| | ASLB | | | | | 88 2 1 |

FIGURE 12: MOTOROLA INSTRUCTION SET

| | | IMMED 0P ~ # | DIRECT OP ~ # | INDEX OP ~ # | EXTND OP ~ # | IMPLIED OP ~ # |
|---|---|---|---|---|---|---|
| Shift Right, | ASR | | | 103 7 2 | 119 6 3 | |
| Arithmetic | ASRA | | | | | 71 2 1 |
| | ASRB | | | | | 87 2 1 |
| Shift Right, | LSR | | | 100 7 2 | 116 6 3 | |
| Logic | LSRA | | | | | 68 2 1 |
| | LSRB | | | | | 84 2 1 |
| Store Accmltr | STAA | | 151 4 2 | 167 6 2 | 183 5 3 | |
| | STAB | | 215 4 2 | 231 6 2 | 247 5 3 | |
| Subtract | SUBA | 128 2 2 | 144 3 2 | 160 5 2 | 176 4 3 | |
| | SUBB | 192 2 2 | 208 3 2 | 224 5 2 | 240 4 3 | |
| Subtract Accmltrs | SBA | | | | | 16 2 1 |
| Subtract with | SBCA | 130 2 2 | 146 3 2 | 162 5 2 | 178 4 3 | |
| Carry | SBCB | 194 2 2 | 210 3 2 | 226 5 2 | 242 4 3 | |
| Transfer Accmltrs | TAB | | | | | 22 2 1 |
| | TBA | | | | | 23 2 1 |
| Test, Zero or | TST | 109 7 2 | | 125 6 3 | | |
| Minus | TSTA | | | | | 77 2 1 |
| | TSTB | | | | | 93 2 1 |

INDEX REGISTER AND STACK MANIPULATION INSTRUCTIONS

| | | IMMED 0P | DIRECT OP | INDEX OP | EXTND OP | IMPLIED OP |
|---|---|---|---|---|---|---|
| Compare Index | CPX | 140 3 3 | 156 4 2 | 172 6 2 | 188 5 3 | |
| Decrement Index | DEX | | | | | 9 4 1 |
| Decrement Stack | DES | | | | | 52 4 1 |
| Increment Index | INX | | | | | 8 4 1 |
| Increment Stack | INS | | | | | 49 4 1 |
| Load Index | LDX | 206 3 3 | 222 4 2 | 238 6 2 | 254 5 3 | |
| Load Stack | LDS | 142 3 3 | 158 4 2 | 174 6 2 | 190 5 3 | |
| Store Index | STX | | 223 5 2 | 239 7 2 | 255 6 3 | |
| Store Stack | STS | | 159 5 2 | 175 7 2 | 191 6 3 | |
| Index—Stack | TXS | | | | | 53 4 1 |
| Stack—Index | TSX | | | | | 48 4 1 |

FIGURE 13: MOTOROLA INSTRUCTION SET (continued)

JUMP AND BRANCH INSTRUCTIONS

| OPERATIONS | MNEMONIC | RELATIVE<br>OP ~ # | INDEX<br>OP ~ # | EXTND<br>OP ~ # | IMPLIED<br>OP ~ # |
|---|---|---|---|---|---|
| Branch Always | BRA | 32 4 2 | | | |
| Branch If Carry Clear | BCC | 36 4 2 | | | |
| Branch If Carry Set | BCS | 37 4 2 | | | |
| Branch If = Zero | BEQ | 39 4 2 | | | |
| Branch If ⩾ Zero | BGE | 44 4 2 | | | |
| Branch If > Zero | BGT | 46 4 2 | | | |
| Branch If Higher | BHI | 34 4 2 | | | |
| Branch If ⩽ Zero | BLE | 47 4 2 | | | |
| Branch If Lower or Same | BLS | 35 4 2 | | | |
| Branch If < Zero | BLT | 45 4 2 | | | |
| Branch If Minus | BMI | 43 4 2 | | | |
| Branch If Not Equal Zero | BNE | 38 4 2 | | | |
| Branch If Overflow Clear | BVC | 40 4 2 | | | |
| Branch If Overflow Set | BVS | 41 4 2 | | | |
| Branch If Plus | BPL | 42 4 2 | | | |
| Branch To Subroutine | BSR | 141 8 2 | | | |
| Jump | JMP | | 110 4 2 | 126 3 3 | |
| Jump to Subroutine | JSR | | 173 8 2 | 189 9 3 | |
| No Operation | NOP | | | | 1 2 1 |
| Return from Interrupt | RTI | | | | 59 10 1 |
| Return from Subroutine | RTS | | | | 57 5 1 |
| Software Interrupt | SWI | | | | 63 12 1 |

OP denotes operation code
~ denotes execution time of the instruction in microsecs
# denotes total number of bytes required to specify the instruction

FIGURE 14: MOTOROLA INSTRUCTION SET (continued)

## 5 VELA Software

In most microcomputers, a monitor eprom sets up the system (when power is applied) to accept commands from the user via the keyboard and to display relevant information on either a VDU or 7 segment display. The user is then able to load the program to be executed from a tape recorder or floppy disk.

In the VELA, the monitor routines and the first 17 programmes are all contained in a 4k byte eprom. The contents of this eprom (1C20) are listed in the following pages. Each of the 4096dec codes are actually 8 bit binary codes, but for convenience they are specified as two digit hexadecimal codes. The codes are located between the hexadecimal addresses $F000 and $FFFF(see the VELA memory map, Figure 5). In the software listing, only the memory addresses of the codes at the start of each subroutine are specified. Each line of the listing specifies a complete instruction together with the equivalent mnemonic assembly language.

The convention adopted with the assembly language is as follows:

a) ' # ' signifies the immediate mode of addressing,
b) '$' signifies the direct or extended modes of addressing,
c) ',X,' signifies the indexed mode of addressing.

Some useful subroutines, together with their starting addresses are listed in Table 8.

Future software, in the form of 4k byte eproms will soon be available, as described in Section 2.3.

The second EPROM, ISL2* was launched in September 1984 and contains 'utility' routines such as:

Save & Reload from cassette recorder Download from microcomputer (either serially or parallel) to VELA Hexadecimal user creation program Interactive sequence controller Disassembler with output to printer Fast Data Dump to printer 100 microseconds resolution timer.

The third EPROM, ISL3* will be available December/January 1985 and will contain:

Logic Tutor routines
Graphics dump to printer
More datalogging routines

## 6 SUMMARY OF TECHNICAL SPECIFICATIONS

| | |
|---|---|
| POWER REQUIREMENTS | 8 volts minimum—12 volts maximum DC<br>8 - 9 volts AC maximum ) I = 0.45 Amp(1)<br>(Current drawn depends upon state of 7 segments display) |
| PULSE INPUT | Input impedance ZIN = 1 M<br>Trigger level = 1 volt<br>Maximum input 25 volts |
| ANALOGUE INPUTS | Input impedance ZIN = 1 M<br>Maximum input 50 volts |
| DIGITAL INPUT/OUTPUT PORT | TTL compatible (unbuffered)<br>When configured as outputs, will drive 1 TTL load |
| SYNC OUTPUT | Output impedance ZOUT = 600 ohms<br>Output voltage swing 0 to >4 volts |
| ANALOGUE OUTPUT | Output impedance ZOUT = 600 ohms<br>Output voltage swing -2.5 volts to +2.5 volts |
| MONITOR SOFTWARE | 4k byte |
| EXPANSION SOFTWARE | 12k byte |
| SYSTEM RAM | 4k byte |

(1) If the PIA's are replaced by pin comaptible 6321's, the current consumption falls to i = 300 mA.

> NOTE
>
> The user should NEVER attempt to measure the voltage from the supply used to power-up VELA. The fuse will blow if this is attempted. This also means that one should NOT use the VELA power supply to power external circuitry which VELA is to monitor.

| PROGRAM | DESCRIPTION | COMMENTS |
|---|---|---|
| 00 | DIGITAL VOLTMETER | Samples every 0.5 second, accuracy of voltage measurement 1% FSD |
| 01 | FAST TRANSIENT RECORDER | '0' parameter selects intersample time of 34 micro sec, 'n' parameter selects 50*n micro sec intersampling time. Input must be to analogue channel 1. |
| 02 | TRANSIENT RECORDER | 'n' parameter selects intersample time of 'n' millisecs (time accuracy = 1%), accuracy of voltage measurement = 1% FSD. |
| 03 | SLOW TRANSIENT RECORDER | 'n' parameter selects intersample time of 'n' seconds (time accuracy = 1%). Note each value stored is average of 256 samples taken over a 200 millisec period. |
| 04 | SCALER/FREQUENCY METER | Valid frequency range 1 Hz to 20 kHz Error of measurement is a function of frequency, accuracy better than 1% at frequencies above 100 Hz. |
| 05 | PULSE/MANUAL TIMER | Timing error = 1% over full range of 1 millisec to 65 seconds. Note pulses must be inputted to 'pulse input'. |
| 06 | MULTICHANNEL TIMER | Note that it detects voltage transitions on digital lines of the digital in/out port (the allowed voltage range is zero to +5 volts). |
| 07 )<br>08 )<br>09 ) | STATISTICS OF RANDOM EVENTS | Timing accuracy = 1%<br>(Accuracy is a function of pulse rate) |
| 10 )<br>11 ) | VERSATILE WAVEFORM GENERATOR AND CONTROL SEQUENCER | Code output time periods accurate to = 1% |
| 12 | RAMP GENERATOR | Times accurate to = 1%. |
| 14 | DOUBLE BEAM OSCILLOSCOPE | Only useful for audio waveforms below a frequency of 1 kHz. |
| 15 | TRANSFER DATA TO MICRO-COMPUTER | Parallel handshake requiring 8 data lines (TTL compatible) and 1 or 2 control lines (TTL compatible) if no external line drivers used, keep lead length less than 1.5 metres. |
| 16 | USER PROGRAM CREATION | An elementary debugging facility; a 'TRACE' test facility is available. |

```
$F000 CE C000   LDX #$C000
      6F 02     CLR,X,02
      6F 03     CLR,X,03
      6F 00     CLR,X,00
      86 7F     LDAA #$7F
      A7 01     STAA,X,01
      86 3E     LDAA #$3E
      A7 02     STAA,X,02
      A7 03     STAA,X,03
      CE D000   LDX #$D000
      6F 02     CLR,X,02
      6F 03     CLR,X,03
      6F 01     CLR,X,01
      86 FF     LDAA #$FF
      A7 00     STAA,X,00
      C6 3E     LDAB #$3E
      E7 02     STAB,X,02
      E7 03     STAB,X,03
      E6 00     LDAB,X,00
      E6 01     LDAB,X,01
      CE E000   LDX #$E000
      6F 02     CLR,X,02
      6F 03     CLR,X,03
      6F 00     CLR,X,00
      A7 01     STAA,X,01
      C6 36     LDAB #$36
      E7 02     STAB,X,02
      E7 03     STAB,X,03
      39        RTS

$F03C 2C        'H'
      3B        'E'
      4D        'L'
      5D        'L'
      60        'O'
$F041 CE F03C   LDX #$F03C
      A6 00     LDAA,X,00
      BD FFB8   JSR $FFB8
      08        INX
      8C F041   CPX #$F041
      26 F5     BNE $F044
      39        RTS

$F050 CE 0000   LDX #$0000
      6F 00     CLR,X,00
      08        INX
      8C 0008   CPX #$0008
      26 F8     BNE $F053
      39        RTS

$F05C CE 0000   LDX #$0000
      A6 00     LDAA,X,00
      84 0F     ANDA #$0F
      A7 40     STAA,X,40
      08        INX
      8C 0008   CPX #$0008
      26 F4     BNE $F05F
      39        RTS

$F06C 0F        SEI
      BD F000   JSR $F000
      7F E001   CLR $E001
      0E        CLI
      8D DA     BSR $F054
      39        RTS

$F077 8E 007B   LDS #$007B
      8D F0     BSR $F06C
      BD FF1C   JSR $FF1C
      8D C0     BSR $F041
      BD F426   JSR $F426
      BD FD72   JSR $FD72
      BD FF1C   JSR $FF1C
      BD FFB2   JSR $FFB2
      BD FF2A   JSR $FF2A
      BD FF52   JSR $FF52
      8D C7     BSR $F05C
      CE 0003   LDX #$0003
      BD FED1   JSR $FED1
      DE 0C     LDX $000C
      DF 48     STX $0048
      DE 00     LDX $0000
      DF 06     STX $0006
      CE 0003   LDX #$0003
      6F 02     CLR,X,02
      BD FED1   JSR $FED1
      96 0D     LDAA $000D
      97 4A     STAA $004A
      81 11     CMPA #$11
      2A 04     BPL $F0B7
      86 FA     LDAA #$FA
      20 16     BRA $F0CD
      81 28     CMPA #$28
      2A 04     BPL $F0BF
      86 BF     LDAA #$BF
      20 0E     BRA $F0CD
      81 3C     CMPA #$3C
      2A 04     BPL $F0C7
      86 AF     LDAA #$AF
      20 06     BRA $F0CD
      81 50     CMPA #50
      2A 17     BPL $F0E2
      86 9F     LDAA #$9F
      97 0C     STAA $000C
      78 000D   ASL $000D
      DE 0C     LDX $000C
      EE 00     LDX,X,00
      6E 00     JMP,X,00
$F0D8 7F 001A   CLR $001A
      CE 0003   LDX #$0003
      BD FE4D   JSR $FE4D
      39        RTS

$F0E2 8E 007B   LDS #$007B
      8D 85     BSR $F066
      20 9B     BRA $F084

$F0E9 96 49     LDAA $0049
      81 01     CMPA #$01
      26 06     BNE $F0F5
      86 3C     LDAA #3C
      C6 3E     LDAB #$3E
      20 18     BRA $F10D
      81 02     CMPA #$02
      26 06     BNE $F0FF
      86 3E     LDAA #$3E
      C6 3C     LDAB #$3C
      20 0E     BRA $F10D
      81 03     CMPA #$03
      26 06     BNE $F109
      86 3C     LDAA #$3C
      C6 3C     LDAB #$3C
      20 04     BRA $F10D
      C6 3E     LDAB #$3E
      86 3E     LDAA #$3E
      B7 D002   STAA $D002
      39        RTS

$F111 8D 5F     BSR $F172
      8D D4     BSR $F0E9
      37        PSHA
      B6 D000   LDAA $D000
      8D 44     BSR $F15F
      B6 D000   LDAA $D000
      33        PULA
      F7 D002   STAB $D002
      C6 A2     LDAB #$A2
      5A        DECB
      26 FD     BNE $F124
      7C 0011   INC $0011
      26 18     BNE $F144
      7C 0010   INC $0010
      26 08     BNE $F139
      BD F225   JSR $F225
      BD F21A   JSR $F21A
      20 F8     BRA $F131
      96 10     LDAA $0010
      84 01     ANDA #$01
      27 02     BEQ $F141
      86 40     LDAA #$40
      B7 E001   STAA $E001
      B6 D002   LDAA $D002
      84 80     ANDA #$80
      26 07     BNE $F152
      B6 C000   LDAA $C000
      84 40     ANDA #$40
      26 D0     BNE $F122
      8D 22     BSR $F176
      BD FD7F   JSR $FD7F
      BD FE29   JSR $FE29
      BD F426   JSR $F426
      20 B4     BRA $F113
$F15F CE 0000   LDX #$0000
      DF 10     STX $0010
      B6 D002   LDAA $D002
      84 80     ANDA #$80
      26 07     BNE $F172
      B6 C000   LDAA $C000
      84 80     ANDA #$80
      26 F2     BNE $F164
      BD FF1C   JSR $FF1C
      39        RTS

$F176 96 10     LDAA $0010
      D6 11     LDAB $0011
      CE 0003   LDX #$0003
      BD FE8E   JSR $FE8E
      BD FE38   JSR $FE38
      39        RTS

$F184 BD FE19   JSR $FE19
      F6 E000   LDAB $E000
      BD F538   JSR $F538
      8D E3     BSR $F172
      CE 0000   LDX #$0000
      DF 34     STX $0034
      CE 8000   LDX #$8000
      B6 C000   LDAA $C00C
      84 80     ANDA #$80
      26 E9     BNE $F187
      BD F9C3   JSR $F9C3
      97 33     STAA $0033
      A7 00     STAA,X,00
      D6 34     LDAB $0034
      E7 01     STAB,X,01
      D6 35     LDAB $0035
      E7 02     STAB,X,02
      08        INX
      08        INX
      08        INX
      DF 3D     STX $003D
      C6 A0     LDAB #$A0
      5A        DECB
      26 FD     BNE $F1B4
      B6 C000   LDAA $C000
      84 40     ANDA #$40
      27 1E     BEQ $F1DC
      DE 34     LDX $0034
      08        INX
      DF 34     STX $0034
      96 34     LDAA $0034
      84 02     ANDA #$02
      26 05     BNE $F1EE
      7F E001   CLR $E001
      20 03     BRA $F1D1
      BD FE29   JSR $FE29
      B6 E000   LDAA $E000
      91 33     CMPA $0033
      27 DA     BEQ $F1B2
      DE 3D     LDX $003D
      20 C5     BRA $F1A1
      BD FF1C   JSR $FF1C
      CE 8000   LDX #$8000
      E6 00     LDAB,X,00
      DF 34     STX $0034
      BD F538   JSR $F538
```

```
      8D 18     BSR $F203
      A6 01     LDAA,X,01
      E6 02     LDAB,X,02
      BD F17A   JSR $F17A
      BD FD7F   JSR $FD7F
      BD FE29   JSR $FE29
      8D 09     BSR $F203
      08        INX
      08        INX
      08        INX
      9C 3D     CPX $003D
      26 E1     BNE $F1E2
      20 D9     BRA $F1DC
      BD FE00   JSR $FE00
      81 0F     CMPA #$0F
      27 0A     BEQ $F214
      B6 C000   LDAA $C000
      84 10     ANDA #$10
      26 F2     BNE $F203
      7E F8E2   JMP $F8E2
      BD FF1C   JSR $FF1C
      DE 34     LDX $0034
      39        RTS

$F21A DF 1C     STX $001C
      CE F421   LDX $F421
      09        DEX
      26 FD     BNE $F21F
      DE 1C     LDX $001C
      39        RTS

$F225 BD FF1C   JSR $FF1C
      86 6C     LDAA #$6C
      8D 02     BSR $F22E
      86 71     LDAA #$71
      BD FFB8   JSR $FFB8
      39        RTS

$F232 BD FF1C   JSR $FF1C
      B6 D000   LDAA $D000
      01 01     NOP,NOP
      CE 0000   LDX #$0000
      6F 10     CLR,X,10
      6F 11     CLR,X,11
      B6 D002   LDAA $D002
      84 80     ANDA #$80
      27 06     BEQ $F25E
      8D DB     BSR $F225
      8D CE     BSR $F21A
      20 E7     BRA $F235
      B6 D000   LDAA $D000
      B6 D002   LDAA $D002
      84 80     ANDA #$80
      27 0D     BEQ $F265
      B6 D000   LDAA $D000
      7C 0011   INC $0011
      26 03     BNE $F263
      7C 0010   INC $0010
      20 09     BRA $F26E
      01 01 01  NOP,NOP,NOP
      01 01 01  NOP,NOP,NOP
      01 01 01  NOP,NOP,NOP
      08        INX
      8C 64A0   CPX #$64A0
      26 DD     BNE $F251
      BD F176   JSR $F176
      BD FE2D   JSR $FE2D
      20 B9     BRA $F235
$F27C B6 D002   LDAA $D002
      84 80     ANDA #$80
      27 F9     BEQ $F27C
      B6 D000   LDAA $D000
      39        RTS

$F287 5F        CLRB
      D7 1E     STAB $001E
      D7 1F     STAB $001F
      37        PSHB
      8D 11     BSR $F2A0
      0C        CLC
      9B 1F     ANDA $001F
      97 1F     STAA $001F
      24 03     BCC $F299
      7C 001E   INC $001E
      33        PULB
      5A        DECB
      26 EF     BNE $F28C
      96 1E     LDAA $001E
      39        RTS

$F2A0 86 36     LDAA #$36
      C6 3E     LDAB #$3E
      B7 D003   STAA $D003
      F7 D003   STAB $D003
      7D D003   TST $D003
      2A FB     BPL $F2AA
      B6 D001   LDAA $D001
      39        RTS

$F2B3 36        '1'
      36
      3E        '2'
      36
      36        '3'
      3E
      3E        '4'
      3E
$F2BB CE 01F2   LDX #$01F2
      DF 2F     STX $002F
      BD FF1C   JSR $FF1C
      7F 002D   CLR $002D
      BD FDEE   JSR $FDEE
      96 2F     LDAA $002F
      36        PSHA
      BD FFB8   JSR $FFB8
      32        PULA
      BD F609   JSR $F609
      8D B2     BSR $F287
      81 FD     CMPA #$FD
      23 05     BLS $F2DE
      BD F225   JSR $F225
      20 0E     BRA $F2EC
      81 01     CMPA #$01
      22 05     BHI $F2E7
      BD F38E   JSR $F38E
      20 05     BRA $F2EC
      BD FCF1   JSR $FCF1
      8D 08     BSR $F2F4
      BD F21A   JSR $F21A
      20 CF     BRA $F2C0
$F2F1 7F 002D   CLR $002D
      86 C3     LDAA #$C3
      97 2E     STAA $002E
      96 1E     LDAA $001E
      81 80     CMPA #$80
      2A 04     BPL $F302
      7C 002D   INC $002D
      40        NEGA
      80 80     SUBA #$80
      7F 000C   CLR $000C
      97 0D     STAA $000D
      96 2E     LDAA $002E
      BD FEFB   JSR $FEFB
      96 10     LDAA $0010
      D6 11     LDAB $0011
      CE 0003   LDX #$0003
      BD FE8E   JSR $FE8E
      C6 05     LDAB #$05
      A6 03     LDAA,X,03
      2D 08     BLT $F327
      6C 02     INC,X,02
      81 0A     CMPA #$0A
      26 02     BNE $F327
      6F 02     CLR,X,02
      C6 0A     LDAB #$0A
      A6 02     LDAA,X,02
      11        CBA
      26 04     BNE $F332
      6F 02     CLR,X,02
      6C 01     INC,X,01
      09        DEX
      8C 0001   CPX #$0001
      26 F1     BNE $F329
      DE 04     LDX $0004
      DF 06     STX $0006
      DE 02     LDX $0002
      DF 04     STX $0004
      7F 0003   CLR $0003
      BD F0D8   JSR $F0D8
      86 8F     LDAA #$8F
      97 32     STAA $0032
      86 FB     LDAA #$FB
      9B 2F     ADDA $002F
      97 33     STAA $0033
      DE 32     LDX $0032
      A6 00     LDAA,X,00
      81 64     CMPA #$64
      26 09     BNE $F361
      BD FDA4   JSR $FDA4
      96 06     LDAA $0006
      8B 60     ADDA #$60
      20 1D     BRA $F37E
      81 0A     CMPA #$0A
      26 09     BNE $F36E
      BD FD9C   JSR $FD9C
      96 05     LDAA $0005
      8B 50     ADDA #$50
      20 10     BRA $F37E
      BD FD9C   JSR $FD9C
      86 4F     LDAA #$4F
      D6 2D     LDAB $002D
      27 02     BEQ $F379
      86 4A     LDAA #$4A
      BD FD88   JSR $FD88
      20 0C     BRA $F38A
      BD FD88   JSR $FD88
      96 2D     LDAA $002D
      27 05     BEQ $F38A
      86 4A     LDAA #$4A
      BD FFB8   JSR $FFB8
      BD FE25   JSR $FE25
      39        RTS

$F38E BD FF1C   JSR $FF1C
      86 6D     LDAA #$6D
      8D 02     BSR $F397
      86 70     LDAA #$70
      BD FFB8   JSR $FFB8
      39        RTS

$F39B BD FE11   JSR $FE11
      86 8C     LDAA #$8C
      9B 48     ADDA $0048
      97 48     STAA $0048
      DE 48     LDX $0048
      DF 21     STX $0021
      BD FF1C   JSR $FF1C
      8D 57     BSR $F407
      B6 C000   LDAA $C000
      84 80     ANDA #$80
      26 06     BNE $F3BA
      BD FCF1   JSR $FCF1
      7E 8C01   JMP $8C01
      BD FE00   JSR $FE00
      D6 20     LDAB $0020
      27 EC     BEQ $F3AD
      81 0B     CMPA #$0B
      26 0D     BNE $F3D2
      DE 21     LDX $0021
      09        DEX
      8C 8C00   CPX #$8C00
      26 D9     BNE $F3A6
      CE 8FFF   LDX #$8FFF
      20 D4     BRA $F3A6
      81 0F     CMPA #$0F
      26 0D     BNE $F3E3
      DE 21     LDX $0021
      08        INX
```

```
        8C 9000  CPX #$9000
        26 C8    BNE $F3A6
        CE 8C01  LDX #$8C01
        20 C3    BRA $F3A6
        8D 02    BSR $F3E7
        20 C1    BRA $F3A8
$F3E7   36       PSHA
        BD F050  JSR $F050
        86 4F    LDAA #$4F
        BD FF1E  JSR $FF1E
        32       PULA
        BD FF54  JSR $FF54
        CE 0003  LDX #$0003
        BD FED1  JSR $FED1
        DE 21    LDX $0021
        96 0D    LDAA $000D
        D6 0C    LDAB $000C
        27 02    BEQ $F404
        86 01    LDAA #$01
        A7 00    STAA,X,00
        39       RTS

$F407   E6 00    LDAB,X,00
        4F       CLRA
        CE 0003  LDX #$0003
        BD FE8E  JSR $FE8E
        7F 001A  CLR $001A
        BD FE4D  JSR $FE4D
        96 21    LDAA $0021
        84 03    ANDA #$03
        D6 22    LDAB $0022
        CE FFFF  LDX #$FFFF
        BD FE8E  JSR $FE8E
        BD FDAD  JSR $FDAD
        39       RTS

$F426   8D 02    BSR $F42A
        8D 00    BSR $F42A
        BD F21A  JSR $F21A
        39       RTS

$F42E   BD FE11  JSR $FE11
        86 01    LDAA #$01
        97 23    STAA $0023
        20 06    BRA $F43D
$F437   7F 0023  CLR $0023
        BD FA45  JSR $FA45
        BD F9E3  JSR $F9E3
        CE 8001  LDX #$8001
        DF 1C    STX $001C
        DF 21    STX $0021
        BD FF1C  JSR $FF1C
        BD F407  JSR $F407
        BD FA22  JSR $FA22
        DE 21    LDX $0021
        A6 00    LDAA,X,00
        B7 E001  STAA $E001
        B6 C000  LDAA $C000
        84 80    ANDA #$80
```

```
        27 2E    BEQ $F48C
        BD FE00  JSR $FE00
        D6 20    LDAB $0020
        27 E8    BEQ $F44D
        81 0B    CMPA #$0B
        26 0D    BNE $F476
        DE 21    LDX $0021
        09       DEX
        8C 8000  CPX #$8000
        26 03    BNE $F474
        CE 80FF  LDX #$80FF
        20 CF    BRA $F445
        81 0F    CMPA #$0F
        26 0D    BNE $F487
        DE 21    LDX $0021
        08       INX
        8C 8100  CPX #$8100
        26 03    BNE $F485
        CE 8001  LDX #$8001
        20 BE    BRA $F445
        BD F3E7  JSR $F3E7
        20 BB    BRA $F447
        DE 21    LDX $0021
        08       INX
        DF 21    STX $0021
        CE 8001  LDX #$8001
        A6 00    LDAA,X,00
        B7 E001  STAA $E001
        BD FE33  JSR $FE33
        DF 24    STX $0024
        DE 48    LDX $0048
        27 49    BEQ $F4EB
        DF 26    STX $0026
        96 23    LDAA $0023
        27 05    BEQ $F4AD
        BD F428  JSR $F428
        20 02    BRA $F4AF
        8D 55    BSR $F504
        BD FE00  JSR $FE00
        D6 20    LDAB $0020
        27 04    BEQ $F4BA
        81 0A    CMPA #$0A
        27 19    BEQ $F4D3
        DE 26    LDX $0026
        09       DEX
        26 E3    BNE $F4A2
        DE 24    LDX $0024
        08       INX
        9C 21    CPX $0021
        26 CE    BNE $F494
        96 23    LDAA $0023
        27 C7    BEQ $F491
        B6 C000  LDAA $C000
        84 80    ANDA #$80
        26 F9    BNE $F4CA
        20 BE    BRA $F491
        BD FF1C  JSR $FF1C
        BD FE00  JSR $FE00
        D6 20    LDAB $0020
        27 F9    BEQ $F4D6
```

```
        81 0D    CMPA #$0D
        26 06    BNE $F4E7
        DE 21    LDX $0021
        09       DEX
        7E F443  JMP $F443
        8D 26    BSR $F50F
        20 A6    BRA $F491
        CE 8001  LDX #$8001
        A6 00    LDAA,X,00
        BD FE33  JSR $FE33
        B7 E001  STAA $E001
        BD FE00  JSR $FE00
        81 0A    CMPA #$0A
        27 D6    BEQ $F4D3
        08       INX
        9C 21    CPX $0021
        26 EC    BNE $F4EB
        20 E7    BRA $F4E8
$F504   36       PSHA
        86 96    LDAA #$96
        4A       DECA
        26 FD    BNE $F507
        32       PULA
        39       RTS

$F50C   BD FF1C  JSR $FF1C
        BD F050  JSR $F050
        BD FF60  JSR $FF60
        CE 0003  LDX #$003
        BD FED1  JSR $FED1
        DE 0C    LDX $000C
        DF 48    STX $0048
        39       RTS

$F520   8D 73    BSR $F595
        D6 49    LDAB $0049
        17       TBA
        BD FE33  JSR $FE33
        F7 E001  STAB $E001
        8D 0B    BSR $F538
        BD FE00  JSR $FE00
        81 0A    CMPA #$0A
        26 F9    BNE $F52C
        8D 63    BSR $F599
        20 E8    BRA $F520
$F538   7F 0038  CLR $0038
        4F       CLRA
        58       ASLB
        99 38    ADCA $0038
        BD FFB8  JSR $FFB8
        86 10    LDAA #$10
        9B 38    ADDA $0038
        97 38    STAA $0038
        81 80    CMPA #$80
        26 EF    BNE $F53A
        39       RTS

$F54D   BD FF1C  JSR $FF1C
```

```
        0F       SEI
        9F 2E    STS $002E
        CE 0030  LDX $0030
        32       PULA
        A7 00    STAA,X,00
        08       INX
        8C 0037  CPX #$0037
        26 F7    BNE $F556
        DE 35    LDX $0035
        09       DEX
        DF 35    STX $0035
        DF 10    STX $0010
        8D 23    BSR $F58A
        DE 33    LDX $0033
        DF 10    STX $0010
        8D 1D    BSR $F58B
        7F 0010  CLR $0010
        96 32    LDAA $0032
        97 11    STAA $0011
        8D 14    BSR $F58B
        96 31    LDAA $0031
        97 11    STAA $0011
        8D 0E    BSR $F58B
        D6 30    LDAB $0030
        8D B7    BSR $F538
        8D 0B    BSR $F58E
        DE 2E    LDX $002E
        DF 10    STX $0010
        8D 02    BSR $F58B
        20 D7    BSR $F561

$F58B   BD F176  JSR $F176
        BD FE00  JSR $FE00
        81 0F    CMPA #$0F
        26 F9    BNE $F58E
        BD FF1C  JSR $FF1C
        39       RTS

$F599   8D FA    BSR $F595
        BD F050  JSR $F050
        BD FF52  JSR $FF52
        BD F515  JSR $F515
        39       RTS

        CE 8001  LDX #$8001
        DF 23    STX $0023
        DF 25    STX $0025
        DF 27    STX $0027
        DF 2B    STX $002B
        CE 0001  LDX #$0001
        DF 29    STX $0029
        BD FE11  JSR $FE11
        86 F2    LDAA #$F2
        97 30    STAA $0030
        BD FF1C  JSR $FF1C
        86 01    LDAA #$01
        97 2F    STAA $002F
        BD FFB8  BSR $FFB8
$F5C6   96 29    LDAA $0029
        D6 2A    LDAB $002A
```

```
        BD F41C  JSR $F41C
        39       RTS

$F5CE   86 01    LDAA #$01
        36       PSHA
        7F 002D  CLR $002D
        8D 35    BSR $F60B
        BD F287  JSR $F287
        DE 2B    LDX $002B
        A7 00    STAA,X,00
        86 04    LDAA #$04
        9B 2B    ADDA $002B
        97 2B    STAA $002B
        32       PULA
        4C       INCA
        81 05    CMPA #$05
        26 E7    BNE $F5D0
        39       RTS

$F5EA   96 2F    LDAA $002F
        36       PSHA
        BD FFB8  JSR $FFB8
        32       PULA
        48       ASLA
        48       ASLA
        8B 80    ADDA #$80
        97 27    STAA $0027
        80 04    SUBA #$04
        97 25    STAA $0025
        8D 25    BSR $F622
        DE 2B    LDX $002B
        A6 00    LDAA,X,00
        97 1E    STAA $001E
        39       RTS

$F604   CE 01F2  LDX #$01F2
        DF 2F    STX $002F
$F609   96 2F    LDAA $002F
$F60B   48       ASLA
        C6 B1    LDAB #$B1
        1B       ABA
        97 31    STAA $0031
        DE 30    LDX $0030
        A6 00    LDAA,X,00
        B7 E002  STAA $E002
        A6 01    LDAA,X,01
        B7 E003  STAA $E003
        39       RTS

$F61E   48       ASLA
        48       ASLA
        8B 7C    ADDA #$7C
$F622   D6 2B    LDAB $002B
        C4 03    ANDB #$03
        1B       ABA
        97 2B    STAA $002B
        39       RTS
```

```
$F62A   C6 3E    LDAB #$3E
        F7 E002  STAB $E002
$F62F   C6 36    LDAB #$36
        F7 E002  STAB $E002
        39       RTS

$F635   BD F9C9  JSR $F9C9
        BD F15F  JSR $F15F
        BD F5A5  JSR $F5A5
        8D DE    BSR $F5CE
        8D A8    BSR $F5EA
        BD F2F1  JSR $F2F1
        DE 2B    LDX $002B
        08       INX
        DF 2B    STX $002B
        DE 29    LDX $0029
        08       INX
        8C 03F9  CPX #$03F9
        26 05    BNE $F657
        8D DB    BSR $F62F
        7E F746  JMP $F746
$F657   DF 29    STX $0029
        DE 48    LDX $0048
        DF 21    STX $0021
        7F E001  CLR $E001
        B6 C000  LDAA $C000
        84 40    ANDA #$40
        27 EB    BEQ $F652
        86 02    LDAA #$02
        36       PSHA
        8D 1E    BSR $F68A
        32       PULA
        4A       DECA
        26 F9    BNE $F669
        BD FE00  JSR $FE00
        D6 20    LDAB $0020
        27 03    BEQ $F67A
        BD FDF4  JSR $FDF4
        BD FE25  JSR $FE25
        BD F5EA  JSR $F5EA
        BD F2F1  JSR $F2F1
        DE 21    LDX $0021
        09       DEX
        26 D3    BNE $F65B
        20 BB    BRA $F645
$F68A   BD F5C6  JSR $F5C6
        BD F10B  JSR $F10B
        4F       CLRA
        B7 D000  STAA $D000
        C6 40    LDAB #$40
        5A       DECB
        26 FD    LDAB #$36
        F7 D002  STAB $D002
        DE 25    LDX $0025
        DF 23    STX $0023
        4F       CLRA
        4C       INCA
        97 3E    STAA $003E
```

```
        CE 0000  LDX #$0000
        DF 1E    STX $001E
        BD F61E  JSR $F61E
        86 FF    LDAA #$FF
        36       PSHA
        96 3E    LDAA $003E
        BD F60B  JSR $F60B
        DE 23    LDX $0023
        A6 00    LDAA,X,00
        BD FE33  JSR $FE33
        08       INX
        DF 23    STX $0023
        8D 18    BSR $F6DA
        32       PULA
        4A       DECA
        26 EA    BNE $F6B0
        96 1E    LDAA $001E
        DE 2B    LDX $002B
        A7 00    STAA,X,00
        96 3E    LDAA $003E
        4C       INCA
        81 05    CMPA #$05
        26 D1    BNE $F6A4
$F6D3   CE 2D00  LDX #$2D00
        09       DEX
        26 FD    BNE $F6D6
        39       RTS

$F6DA   BD F2A0  JSR $F2A0
        0C       CLC
        9B 1F    ADDA $001F
        97 1F    STAA $001F
        24 03    BCC $F6E7
        7C 001E  INC $001E
        39       RTS

$F6E8   BD F9C9  JSR $F9C9
        BD F15F  JSR $F15F
        BD F10B  JSR $F10B
        CE 8001  LDX #$8001
        DF 2B    STX $002B
        DE 48    LDX $0048
        DF 21    STX $0021
        7F 002F  CLR $002F
        7C 002F  INC $002F
        96 2F    LDAA $002F
        BD F61E  JSR $F61E
        BD F609  JSR $F609
        BD F2A0  JSR $F2A0
        DE 2B    LDX $002B
        A7 00    STAA,X,00
        BD FE33  JSR $FE33
        96 2F    LDAA $002F
        81 04    CMPA #$04
        26 E5    BNE $F6FD
        C6 20    LDAB #$20
        5A       DECB
        26 FD    BNE $F71A
        B6 C000  LDAA $C000
        84 40    ANDA #$40
```

```
$F722   27 1F    BEQ $F743
        DE 21    LDX $0021
        09       DEX
        26 CF    BNE $F6F8
        DE 2B    LDX $002B
        08       INX
        96 2C    LDAA $002C
        84 04    ANDA #$04
        26 03    BNE $F735
        BD FE29  JSR $FE29
        96 2C    LDAA $002C
        84 08    ANDA #$08
        26 03    BNE $F73E
        7F E001  CLR $E001
        8C 8FF9  CPX #$8FF9
        26 B1    BNE $F6F4
        BD F62F  JSR $F62F
$F746   CE 8000  LDX #$8000
        DF 27    STX $0027
        08       INX
        DF 23    STX $0023
        DF 25    STX $0025
        DF 2B    STX $002B
        CE 0001  LDX #$0001
        DF 29    STX $0029
        BD FE00  JSR $FE00
        D6 20    LDAB $0020
        26 0E    BNE $F76C
        BD FD38  JSR $FD38
        BD F9F9  JSR $F9F9
        BD FF1C  JSR $FF1C
        BD F9F9  JSR $F9F9
        20 EB    BRA $F757
        BD FDF0  JSR $FDF0
        BD F5EA  JSR $F5EA
        B6 C000  LDAA $C000
        84 10    ANDA #$10
        26 03    BNE $F77C
        7E F8FB  JMP $F8FB
        BD FF1C  JSR $FF1C
        BD FE00  JSR $FE00
        D6 20    LDAB $0020
        27 E6    BEQ $F76C
        81 0A    CMPA #$0A
        27 BC    BEQ $F746
        81 0C    CMPA #$0C
        26 03    BNE $F791
        7E FC60  JMP $FC60
        81 0D    CMPA #$0D
        26 D7    BNE $F76C
$F795   BD F806  JSR $F806
        4F       CLRA
        BD FE00  JSR $FE33
        BD FCA5  JSR $FCA5
        BD FE00  JSR $FE00
        D6 20    LDAB $0020
        26 06    BNE $F7AC
        D6 30    LDAB $0030
        27 23    BEQ $F7CD
```

```
        20 17     BRA $F7C3
        81 0B     CMPA #$0B
        26 04     BNE $F7B4
        8D 23     BSR $F7D5
        20 E1     BRA $F795
        81 0F     CMPA #$0F
        26 04     BNE $F7BC
        8D 3B     BSR $F7F5
        20 D9     BRA $F795
        81 0A     CMPA #$0A
        26 D5     BNE $F795
        7E F746   JMP $F746
        CE 8001   LDX #$8001
        DF 25     STX $0025
        CE 8400   LDX #$8400
        DF 27     STX $0027
        BD FCA5   JSR $FCA5
        BD F5EA   JSR $F5EA
        20 C3     BRA $F798
$F7D5   8D 10     BSR $F7E7
        9C 25     CPX $0025
        27 06     BEQ $F7E1
        09        DEX
        5A        DECB
        26 F8     BNE $F7D7
        20 03     BRA $F7E4
        DE 27     LDX $0027
        09        DEX
        DF 2B     STX $002B
        39        RTS

$F7E7   DE 2B     LDX $002B
        C6 01     LDAB #$01
        B6 C000   LDAA $C000
        84 20     ANDA #$20
        26 02     BNE $F7F4
        C6 10     LDAB #$10
        39        RTS

$F7F5   8D F0     BSR $F7E7
        08        INX
        9C 27     CPX $0027
        27 05     BEQ $F801
        5A        DECB
        26 F8     BNE $F7F7
        20 02     BRA $F803
        DE 25     LDX $0025
        DF 2B     STX $002B
        39        RTS

$F806   BD F5EA   JSR $F5EA
        BD F2F1   JSR $F2F1
        BD FD51   JSR $FD51
        39        RTS

$F810   B6 D000   LDAA $D000
        BD F9D0   JSR $F9D0
        CE 7FFF   LDX #7FFF
        DF 2B     STX $002B

        BD F15F   JSR $F15F
        BD F10B   JSR $F10B
        DE 48     LDX $0048
        26 1B     BNE $F840
        DE 2B     LDX $002B
        C6 2E     LDAB #$2E
$F829   F7 D003   STAB $D003
        F7 D001   STAF $D001
        08        INX
        8C 8FF9   CPX #$8FF9
        27 08     BEQ $F83D
        B6 D001   LDAA $D001
        A7 00     STAA,X,00
        7E F829   JMP $F829
        7E F746   JMP $F746
$F840   8C 0001   CPX #$0001
        26 1B     BNE $F860
        DE 2B     LDX $002B
        C6 2E     LDAB #$2E
$F849   F7 D003   STAB $D003
        F7 D001   STAB $D001
        08        INX
        BD F7F4   JSR $F7F4
        8C 8FF9   CPX #$8FF9
        27 E5     BEQ $F83D
        B6 D001   LDAA $D001
        A7 00     STAA,X,00
        7E F849   JMP $F849
$F860   DE 48     LDX $0048
        09        DEX
        86 36     LDAA #$36
        C6 3E     LDAB #$3E
        B7 D003   STAA $D003
        F7 D003   STAB $D003
        7D D003   TST $D003
        2A FB     BPL $F86D
        B6 D001   LDAA $D001
        01 01     NOP,NOP
        09        DEX
        26 E9     BNE $F863
        BD F7F4   JSR $F7F4
        DE 2B     LDX $002B
        08        INX
        A7 00     STAA,X,00
        DF 2B     STX $002B
        8C 8FF8   CPX $8FF8
        26 D7     BNE $F860
        20 B2     BRA $F83D
$F88B   BD F2A0   JSR $F2A0
        9B 32     ADDA $0032
        43        COMA
        B7 D000   STAA $D000
        86 36     LDAA #$36
        B7 E002   STAA $E002
        B7 E003   STAA $E003
        BD F2A0   JSR $F2A0
        90 33     SUBA $0033
        43        COMA
        B7 D000   STAA $D000

        B6 C002   LDAA $C002
        39        RTS

        01 01 01  NOP,NOP,NOP
$F8AC   BD FF1C   JSR $FF1C
        BD FDEE   JSR $FDEE
        D6 20     LDAB $0020
        27 F9     BEQ $F8AF
        BD FFB8   JSR $FFB8
        8D 10     BSR $F8CB
        BD F5EA   JSR $F5EA
        B6 C000   LDAA $C000
        84 10     ANDA #$10
        26 F9     BNE $F8BE
        CE F0E2   LDX #$F0E2
        7E F8FE   JMP $F8FE
$F8CB   7F 0044   CLR $0044
        4F        CLRA
        97 26     STAA $0026
        97 28     STAA $0028
        39        RTS

$F8D4   0C        CLC
        96 3E     LDAB $003E
        90 3C     SUBA $003C
        97 40     STAA $0040
        96 3D     LDAA $003D
        92 3B     SBCA $003B
        97 3F     STAA $003F
        39        RTS

$F8E2   CE F214   LDX #$F214
        DF 45     STX $0045
        CE 8000   LDX #$8000
        DF 3B     STX $003B
        7F 0044   CLR $0044
        8D E3     BSR $F8D4
        20 1B     BRA $F80E
$F8F3   BD F8CB   JSR $F8CB
        CE FB93   LDX #$FB93
        20 03     BRA $F8FE
$F8FB   CE F746   LDX #$F746
        DF 45     STX $0045
        DE 25     LDX $0025
        DF 3B     STX $003B
        DE 27     LDX $0027
        DF 3D     STX $003D
        8D CA     BSR $F8D4
        96 2F     LDAA $002F
        97 44     STAA $0044
        8B FB     ADDA #$FB
        97 53     STAA $0053
        86 8F     LDAA #$8F
        97 52     STAA $0052
        DE 48     LDX $0048
        DF 42     STX $0042
        96 4A     LDAA $004A
        97 41     STAA $0041
        B6 E000   LDAA $E000
        CE 003F   LDX #$003F
        8D 15     BSR $F93B

        08        INX
        8C 0045   CPX #$0045
        26 F8     BNE $F924
        DE 52     LDX $0052
        8D 0B     BSR $F93B
        DE 3B     LDX $003B
        8D 07     BSR $F93B
        08        INX
        9C 3D     CPX $003D
        26 F9     BNE $F932
        20 12     BRA $F94D
$F93B   E6 00     LDAB,X,00
        F7 E001   STAB $E001
        BD F62A   JSR $F62A
        8D 0C     BSR $F951
        39        RTS

$F946   BD FE00   JSR $FE00
        81 0A     CMPA #$0A
        26 04     BNE $F951
$F94D   DE 45     LDX $0045
        6E 00     JMP,X,00
        F6 E002   LDAB $E002
        C4 80     ANDB #$80
        27 EE     BEQ $F946
        F6 E000   LDAB $E000
        39        RTS

$F95C   86 F2     LDAA #$F2
        97 30     STAA $0030
        DE 48     LDX $0048
        26 04     BNE $F968
        DF 32     STX $0032
        20 18     BRA $F980
        96 49     LDAA $0049
        84 01     ANDA #$01
        27 0B     BEQ $F979
        96 49     LDAA $0049
        4A        DECA
        44        LSRA
        97 32     STAA $0032
        4C        INCA
        97 33     STAA $0033
        20 07     BRA $F980
        96 49     LDAA $0049
        44        LSRA
        97 32     STAA $0032
        97 33     STAA $0033
        BD FF1C   JSR $FF1C
        86 21     LDAA #$21
        BD FFB8   JSR $FFB8
        86 4A     LDAA #$4A
        BD FFB8   JSR $FFB8
        86 6A     LDAA #$6A
        BD FFB8   JSR $FFB8
        BD F21A   JSR $F21A
        BD FDEE   JSR $FDEE
        D6 20     LDAB $0020
        26 0A     BNE $F9A6
```

```
        86 6F     LDAA #$6F
        BD FFB8   JSR $FFB8
        BD F21A   JSR $F21A
        20 E7     BRA $F98B
        96 2F     LDAA $002F
        8B 60     ADDA #$60
        BD FFB8   JSR $FFB8
        BD F609   JSR $F609
        BD F88B   JSR $F88B
        B6 C003   LDAA $C003
        84 80     ANDA #$80
        27 F3     BEQ $F9AD
        BD FFCF   JSR $FFCF
        81 0A     CMPA #$0A
        26 EC     BNE $F9AD
        20 BD     BRA $F980
$F9C3   8D 04     BSR $F9C9
        CE 8000   LDX #$8000
        39        RTS

$F9C9   86 F2     LDAA #$F2
        97 30     STAA $0030
        8D 1B     BSR $F9EA
        39        RTS

$F980   8D 1B     BSR $F9ED
        CE 8FFC   LDX #$8FFC
        A6 00     LDAA,X,00
        A7 01     STAA,X,01
        A7 02     STAA,X,02
        A7 03     STAA,X,03
        39        RTS

$F9DE   8D 03     BSR $F9E3
        8D 08     BSR $F9EA
        39        RTS

$F9E3   BD F604   JSR $F604
        BD FCF1   JSR $FCF1
        39        RTS

$F9EA   BD FE11   JSR $FE11
$F9ED   86 5F     LDAA #$5F
        BD FF1E   JSR $FF1E
        BD FE10   JSR $FE10
        BD FCF1   JSR $FCF1
        39        RTS

$F9F9   CE 1869   LDX #$1869
        09        DEX
        26 FD     BNE $F9FC
        39        RTS
```

```
$FA00   F2BB      '00'
        F810      '01'
        F6E8      '02'
        F635      '03'
        F232      '04'
        F111      '05'
        F184      '06'
        FAE2      '07'
        FA8D      '08'
        FB44      '09'
        F437      '10'
        F42E      '11'
        FD6D      '12'
        F520      '13'
        F95C      '14'
        F8AC      '15'
        F39B      '16'
$FA22   4F        CLRA
        BD FE33   JSR $FE33
        BD F10B   JSR $F10B
        4F        CLRA
        B7 D000   STAA $D000
        C6 40     LDAB #$40
        5A        DECB
        26 FD     BNE $FA2F
        C6 36     LDAB #$36
        F7 D002   STAB $D002
        DE 1C     LDX $001C
        A6 00     LDAA,X,00
        BD FE33   JSR $FE33
        08        INX
        8C 8100   CPX #$8100
        26 F5     BNE $FA39
        39        RTS

$FA45   CE 80FF   LDX #$80FF
        BD FE1C   JSR $FE1C
        39        RTS

$FA4C   0F        SEI
        CE FA59   LDX #$FA59
        DF 7E     STX $007E
        86 3F     LDAA #$3F
        B7 D002   STAA $D002
        0E        CLI
        39        RTS

$FA59   D6 1B     LDAB $001B
        C1 FF     CMPB #$FF
        27 03     BEQ $FA62
        7C 001B   INC $001B
        B6 D000   LDAA $D000
        3B        RTI
$FA66   8D E4     BSR $FA4C
        BD FE11   JSR $FE11
        86 2F     LDAA #$2F
        BD FF1E   JSR $FF1E
        86 80     LDAA #$80
```

```
        97 29     STAA $0029
        5F        CLRB
        D7 21     STAB $0021
        D7 22     STAB $0022
        D7 23     STAB $0023
        D7 24     STAB $0024
        5C        INCB
        D7 2A     STAB $002A
        B6 C000   LDAA $C000
        84 80     ANDA #$80
        26 F9     BNE $FA80
        8D BB     BSR $FA45
        BD F9C9   JSR $F9C9
        39        RTS
$FA8D   8D D9     BSR $FA68
        B6 D000   LDAA $D000
        CE 8001   LDX #8001
        DF 1C     STX $001C
        8D 89     BSR $FA22
        B6 D002   LDAA $D002
        84 80     ANDA #$80
        27 F7     BEQ $FA97
        B6 D000   LDAA $D000
        CE 8000   LDX #$8000
        DF 29     STX $0029
        DE 48     LDX $0048
        DF 1E     STX $001E
        BD FA22   JSR $FA22
        B6 C000   LDAA $C000
        84 40     ANDA #$40
        26 07     BNE $FABD
        86 02     LDAA #$02
        97 30     STAA $0030
        7E FB93   JMP $FB93
        DE 1E     LDX $001E
        09        DEX
        26 E8     BNE $FAAA
        7C 002A   INC $002A
        27 EF     BEQ $FA96
        B6 D002   LDAA $D002
        84 80     ANDA #$80
        27 DE     BEQ $FAAA
        DE 29     LDX $0029
        A6 00     LDAA,X,00
        81 FF     CMPA #$FF
        27 E0     BEQ $FAB6
        4C        INCA
        A7 00     STAA,X,00
        86 01     LDAA #$01
        8D 52     BSR $FB2F
        BD FD5F   JSR $FD5F
        20 AD     BRA $FA8F
$FAE2   8D 82     BSR $FA66
        96 29     LDAA $0029
        81 81     CMPA #$81
        26 03     BNE $FAED
        7E FB93   JMP $FB93
        CE 8001   LDX #$8001
```

```
        DF 1C     STX $001C
        BD FD5F   JSR $FD5F
        7F 001B   CLR $001B
        DE 48     LDX $0048
        DF 1E     STX $001E
        86 64     LDAA #$64
        36        PSHA
        BD FA22   JSR $FA22
        32        PULA
        4A        DECA
        26 F8     BNE $FAFE
        C6 01     LDAB #$01
        5A        DECB
        26 FD     BNE $FB08
        B6 C000   LDAA $C000
        84 40     ANDA #$40
        26 06     BNE $FB18
        86 01     LDAA #$01
        97 30     STAA $0030
        20 D2     BRA $FAEA
        DE 1E     LDX $001E
        09        DEX
        26 DD     BNE $FAFA
        96 1B     LDAA $001B
        DE 29     LDX $0029
        A7 00     STAA,X,00
        8D 0A     BSR $FB2F
        08        INX
        DF 29     STX $0029
        8C 8100   CPX #$8100
        26 C5     BNE $FAF2
        20 E3     BRA $FB12
$FB2F   D6 22     LDAB $0022
        5C        INCB
        26 03     BNE $FB37
        7C 0021   INC $0021
        D7 22     STAB $0022
        0C        CLC
        9B 24     ADDA $0024
        24 03     BCC $FB41
        7C 0023   INC $0023
        97 24     STAA $0024
        39        RTS

$FB44   BD FA66   JS.. $FA66
        CE 8000   LDX #$8000
        DF 1C     STX $001C
        96 21     LDAA $0021
        D6 22     LDAB $0022
        BD F17A   JSR $F17A
        7F 001B   CLR $001B
        DE 48     LDX $0048
        DF 1E     STX $001E
        86 64     LDAA #$64
        36        PSHA
        BD FA22   JSR $FA22
        32        PULA
        4A        DECA
        26 F8     BNE $FB5C
```

```
       C6 01    LDAB #$01
       5A       DECB
       26 FD    BNE $FB66
       B6 C000  LDAA $C000
       84 40    ANDA #$40
       26 06    BNE $FB76
       86 03    LDAA #$03
       97 30    STAA $0030
       20 1D    BRA $FB93
       DE 1E    LDX $001E
       09       DEX
       26 DD    BNE $FB58
       96 1B    LDAA $001B
       97 2A    STAA $002A
       DE 29    LDX $0029
       E6 00    LDAB,X,00
       C1 FF    CMPB #$FF
       27 E9    BEQ $FB70
       6C 00    INC,X,00
       8D A4    BSR $FB2F
       20 BF    BRA $FB4C
$FB8D  FA E4    '07'
       FA 8F    '08'
       FB 47    '09'
$FB93  0F       SEI
       BD FF1C  JSR $FF1C
       4F       CLRA
       BD FE33  JSR $FE33
       CE 8001  LDX #$8001
       DF 25    STX $0025
       DF 2B    STX $002B
       CE 8100  LDX #$8100
       DF 27    STX $0027
       86 FB    LDAA #$FB
       97 2D    STAA $002D
       BD FD12  JSR $FD12
       BD F9F9  JSR $F9F9
       B6 C000  LDAA $C000
       84 80    ANDA #$80
       26 04    BNE $FBBC
       8D 61    BSR $FC1B
       6E 00    JMP,X,00
       BD FF1C  JSR $FF1C
       BD F9F9  JSR $F9F9
       BD FDEE  JSR $FDEE
       D6 20    LDAB $0020
       27 E2    BEQ $FBAB
       BD FFB8  JSR $FFB8
       96 2F    LDAA $002F
       BD FD5B  JSR $FD5B
       B6 C000  LDAA $C000
       84 10    ANDA #$10
       26 03    BNE $FADB
       7E F8F3  JMP $F8F3
       BD FE00  JSR $FE00
       D6 20    LDAB $0020
       27 EF    BEQ $FAD1
       81 0C    CMPA #$0C

       26 03    BNE $FBEA
       7E FC5C  JMP $FC5C
       81 0A    CMPA #$0A
       27 A7    BEQ $FB93
       81 0D    CMPA #$0D
       26 D8    BNE $FAC9
       BD FD46  JSR $FD46
       4F       CLRA
       BD FE33  JSR $FE33
       BD FCA4  JSR $FCA4
       BD FE00  JSR $FE00
       D6 20    LDAB $0020
       27 F6    BEQ $FBF8
       81 0B    CMPA #$0B
       26 05    BNE $FC0B
       BD F7D5  JSR $F7D5
       20 E6    BRA $FBF1
       81 0F    CMPA #$0F
       26 05    BNE $F014
       BD F7F5  JSR $F7F5
       20 DD    BRA $FBF1
       81 0A    CMPA #$0A
       26 D9    BNE $FBF1
       7E FB93  JMP $FB93
$FC1B  BD FF1C  JSR $FF1C
       4F       CLRA
       BD FFB8  JSR $FFB8
       96 30    LDAA $0030
       8B 16    ADDA #$16
       BD FFB8  JSR $FFB8
       0E       CLI
       96 30    LDAA $0030
       48
       8B 8B    ADDA #$8B
       97 2E    STAA $002E
       DE 2D    LDX $002D
       EE 00    LDX,X,00
       39       RTS

$FC36  CE 80FF  LDX #$80FF
       DF 4D    STX $004D
       CE 8000  LDX #$8000
       DF 4B    STX $004B
       CE FB93  LDX #$FB93
       DF 4F    STX $004F
       7F 0051  CLR $0051
       39       RTS

$FC49  DE 27    LDX $0027
       DF 4D    STX $004D
       DE 25    LDX $0025
       09       DEX
       DF 4B    STX $004B
       CE F746  LDX #$F746
       DF 4F    STX $004F
       86 01    LDAA #$01
       97 51    STAA $0051
       39       RTS

$FC5C  8D D8    BSR $FC36
       20 02    BRA $FC62
       8D E7    BSR $FC49
       4F       CLRA
       BD FCDE  JSR $FCDE
       BD FF1C  JSR $FF1C
       BD FE33  JSR $FE33
       BD F426  JSR $F426
       BD FF1C  JSR $FF1C
       DE 4D    LDX $004D
       9C 4B    CPX $004B
       27 29    BEQ $FCA1
       A6 00    LDAA,X,00
       16       TAB
       BD FE33  JSR $FE33
       96 51    LDAA $0051
       27 07    BEQ $FB89
       D7 1E    STAB $001E
       BD F2F1  JSR $F2F1
       20 03    BRA $FB8C
       8D F17A  JSR $F17A
       96 4D    LDAA $004D
       84 03    ANDA #$03
       D6 4E    LDAB $004E
       BD F41C  JSR $F41C
       DE 4D    LDX $004D
       09       DEX
       DF 4D    STX $004F
       BD FE00  JSR $FE00
       81 0A    CMPA #$0A
       26 CB    BNE $FC6C
       DE 4F    LDX $004F
       6E 00    JMP,X,00
$FCA5  BD F10B  JSR $F10B
       86 FF    LDAA #$FF
       BD FE33  JSR $FE33
       C6 0A    LDAB #$0A
       5A       DECB
       26 FD    BNE $FCAF
       BD FD72  JSR $FD72
       DE 25    LDX $0025
       A6 00    LDAA,X,00
       43       COMA
       B7 D000  STAA $D000
       9C 2B    CPX $002B
       26 17    BNE $FCD8
       C6 E7    LDAB #$E7
       F7 D000  STAB $D000
       C0 45    SUBB #$45
       F7 D000  STAB $D000
       C0 45    SUBB #$45
       F7 D000  STAB $D000
       C0 45    SUBB #45
       F7 D000  STAB $D000
       B7 D000  STAA $D000
       08       INX
       9C 27    CPX $0027
       26 DA    BNE $FCB7
       39       RTS

$FCDE  BD FE33  JSR $FE33
       DE 4D    LDX $004D
       09       DEX
       9C 4B    CPX $004B
       26 03    BNE $FCEB
       DF 4D    STX $004D
       39       RTS
       A6 00    LDAA,X,00
       27 F4    BEQ $FCE3
       20 F7    BRA $FCE8
$FCF1  86 10    LDAA #$10
       B7 E001  STAA $E001
       D6 2F    LDAB $002F
       37       PSHB
       CE 8FFF  LDX #$8FFF
       86 04    LDAA #$04
       97 2F    STAA $002F
       DF 32    STX $0032
       BD F609  JSR $F609
       BD F2A0  JSR $F2A0
       80 04    SUBA #$04
       2A 04    BPL $FD10
       86 64    LDAA #$64
       20 0A    BRA $FD1A
       8B 08    ADDA #$08
       2A 04    BPL $FD18
       86 0A    LDAA #$0A
       20 02    BRA $FD1A
       86 01    LDAA #01
       DE 32    LDX $0032
       A7 00    STAA,X,00
       09       DEX
       96 2F    LDAA $002F
       4A       DECA
       26 DA    BNE $FCFE
       7F E001  CLR $E001
       33       PULB
       D7 2F    STAB $002F
       96 4A    LDAA $004A
       A7 00    STAA,X,00
       DE 48    LDX $0048
       FF 8FF9  STX $8FF9
       B6 E000  LDAA $E000
       39       RTS

$FD37  01       NOP
       86 30    LDAA #$30
       8D 06    BSR $FD42
       86 4A    LDAA #$4A
       8D 02    BSR $FD42
       86 5E    LDAA #$5E
       BD FFB8  JSR $FFB8
       39       RTS

$FD46  BD FF1C  JSR $FF1C
       DE 2B    LDX $002B
       4F       CLRA
       E6 00    LDAB,X,00
       BD F17A  JSR $F17A
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      96 2B     LDAA $002B
      84 03     ANDA #$03
      D6 2C     LDAB $002C
      BD F41C   JSR $F41C
      39        RTS

$FD5B 81 01     CMPA #$01
      26 06     BNE $FD65
      96 21     LDAA $0021
      D6 22     LDAB $0022
      20 04     BRA $FD69
      96 23     LDAA $0023
      D6 24     LDAB $0024
      BD F17A   JSR $F17A
      39        RTS

$FD6D 7A D000   DEC $D000
      20 FB     BRA $FD6D
$FD72 F6 D002   LDAB $D002
      CA 08     ORAB #$08
      8D 02     BSR $FD7B
      C4 F7     ANDB #$F7
      F7 D002   STAB $D002
      39        RTS

$FD7F 96 04     LDAA $0004
      8B 40     ADDA #$40
      8D 03     BSR $FD88
      8D 15     BSR $FD9C
      39        RTS

$FD88 C6 36     LDAB #$36
      8D 04     BSR $FD90
      8D 1C     BSR $FDAA
      C6 3E     LDAB #$3E
      F7 C002   STAB $C002
      39        RTS

$FD94 96 04     LDAA $0004
      26 04     BNE $FD9C
      8B 40     ADDA #$40
      8D 0E     BSR $FDAA
      96 05     LDAA $0005
      26 04     BNE $FDA4
      8B 50     ADDA #$50
      8D 06     BSR $FDAA
      96 06     LDAA $0006
      26 04     BNE $FDAC
      8B 60     ADDA #$60
      8D 3E     BSR $FDEA
      39        RTS

$FDAD 7F 001A   CLR $001A
      CE 0000   LDX #$0000
      A6 00     LDAA,X,00
      26 04     BNE $FDBB
      8B 0F     ADDA #$0F
      20 03     BRA $FDBE
      7C 001A   INC $001A
      8D 2A     BSR $FDEA
      A6 01     LDAA,X,01
      26 08     BNE $FDCD
      D6 1A     LDAB $001A
      26 07     BNE $FDD0
      8B 1F     ADDA #$1F
      20 05     BRA $FDD2
      7C 001A   INC $001A
      8B 10     ADDA #$10
      8D 17     BSR $FDEA
      A6 02     LDAA,X,02
      26 08     BNE $FDE0
      D6 1A     LDAB $001A
      26 07     BNE $FDE2
      8B 2F     ADDA #$2F
      20 05     BRA $FDE4
      7C 001A   INC $001A
      8B 20     ADDA #$20
      8D 04     BSR $FDEA
      A6 03     LDAA,X,03
      8B 30     ADDA #$30
      BD FFB8   JSR $FFB8
      39        RTS

$FDEE 8D 10     BSR $FE00
      D6 20     LDAB $0020
      27 0B     BEQ $FDFF
      81 05     CMPA #$05
      2C 07     BGE $FDFF
      81 00     CMPA #$00
      26 01     BNE $FDFD
      4C        INCA
      97 2F     STAA $002F
      39        RTS

$FE00 7F 0020   CLR $0020
      B6 C003   LDAA $C003
      84 80     ANDA #$80
      27 06     BEQ $FE10
      7C 0020   INC $0020
      BD FFCF   JSR $FFCF
      39        RTS

$FE11 DE 48     LDX $0048
      26 03     BNE $FE18
      08        INX
      DF 48     STX $0048
      39        RTS

$FE19 CE 8FFF   LDX #$8FFF
      6F 00     CLR,X,00
      09        DEX
      8C 7FFF   CPX #$7FFF
      26 F8     BNE $FE1C
      39        RTS

$FE25 86 80     LDAA #$80
      20 06     BRA $FE2F
$FE29 86 40     LDAA #$40
      20 02     BRA $FE2F
      86 20     LDAA #$20
      B7 E001   STAA $E001
      39        RTS

$FE33 43        COMA
      B7 D000   STAA $D000
      39        RTS

$FE38 7F 001A   CLR $001A
      CE 0003   LDX #$0003
      A6 00     LDAA,X,00
      26 04     BNE $FE46
      8B 3F     ADDA #$3F
      20 05     BRA $FE4B
      7C 001A   INC $001A
      8B 30     ADDA #$30
      8D 3D     BSR $FE8A
      A6 01     LDAA,X,01
      26 08     BNE $FE59
      D6 1A     LDAB $001A
      26 07     BNE $FE5C
      8B 4F     ADDA #$4F
      20 05     BRA $FE5E
      7C 001A   INC $001A
      8B 40     ADDA #$40
      8D 2A     BSR $FE8A
      A6 02     LDAA,X,02
      26 08     BNE $FE6C
      D6 1A     LDAB $001A
      26 07     BNE $FE6F
      8B 5F     ADDA #$5F
      20 05     BRA $FE71
      7C 001A   INC $001A
      8B 50     ADDA #$50
      8D 17     BSR $FE8A
      A6 03     LDAA,X,03
      26 08     BNE $FE7F
      D6 1A     LDAB $001A
      26 07     BNE $FE82
      8B 6F     ADDA #$6F
      20 05     BRA $FE84
      7C 001A   INC $001A
      8B 60     ADDA #$60
      8D 04     BSR $FE8A
      A6 04     LDAA,X,04
      8B 70     ADDA #$70
      BD FFB8   JSR $FFB8
      39        RTS

$FE8E DF 12     STX $0012
      08        INX
      08        INX
      08        INX
      08        INX
      97 14     STAA $0014
      D7 15     STAB $0015
      86 0A     LDAA #$0A
      97 16     STAA $0016
      DF 17     STX $0017
      8D 0E     BSR $FEAE
      DE 17     LDX $0017
      96 19     LDAA $0019
      A7 00     STAA,X,00
      09        DEX
      9C 12     CPX $0012
      2C F1     BGE $FE9C
      DE 12     LDX $0012
      39        RTS

$FEAE 7F 0019   CLR $0019
      CE 0011   LDX #$0011
      20 06     BRA $FEBC
      96 19     LDAA $0019
      90 16     SUBA $0016
      2A 03     BPL $FEBF
      0C        CLC
      20 03     BRA $FEC2
      97 19     STAA $0019
      0D        SEC
      79 0015   ROL $0015
      79 0014   ROL $0014
      09        DEX
      27 05     BEQ $FED0
      79 0019   ROL $0019
      20 E6     BRA $FEB6
      39        RTS

$FED1 7F 000C   CLR $000C
      7F 000D   CLR $000D
      C6 04     LDAB #$04
      A6 00     LDAA,X,00
      84 0F     ANDA #$0F
      9B 0D     ADDA $000D
      97 0D     STAA $000D
      24 03     BCC $FEE6
      7C 000C   INC $000C
      5A        DECB
      2B 11     BMI $FEFA
      37        PSHB
      DF 0E     STX $000E
      86 0A     LDAA #$0A
      8D 0B     BSR $FEFB
      DE 10     LDX $0010
      DF 0C     STX $000C
      33        PULB
      DE 0E     LDX $000E
      08        INX
      20 DF     BRA $FED9
      39        RTS

$FEFB CE 0008   LDX #$0008
      5F        CLRB
      D7 10     STAB $0010
      D7 11     STAB $0011
      78 0011   ASL $0011
      79 0010   ROL $0010
      48        ASLA
      24 0C     BCC $FF18
      D6 0D     LDAB $000D
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      DB 11    ADDB $0011
      D7 11    STAB $0011
      D6 0C    LDAB $000C
      D9 10    ADCB $0010
      D7 10    STAB $0010
      09       DEX
      26 E8    BNE $FF03
      39       RTS

$FF1C 86 0F    LDAA #$0F
      C6 10    LDAB #$10
      36       PSHA
      8D 2C    BSR $FF4F
      32       PULA
      1B       ABA
      81 8F    CMPA #$8F
      26 F7    BNE $FF20
      39       RTS

$FF2A BD FFC8  JSR $FFC8
      C6 0A    LDAB #$0A
      11       CBA
      2A F8    BPL $FF2A
      8B 10    ADDA #$10
      97 01    STAA $0001
      8D 17    BSR $FF4F
      BD FFC8  JSR $FFC8
      D6 01    LDAB $0001
      C0 10    SUBB #$10
      D7 00    STAB $0000
      36       PSHA
      17       TBA
      8D 73    BSR $FFB8
      32       PULA
      C6 0A    LDAB #$0A
      11       CBA
      2A ED    BPL $FF38
      8B 10    ADDA #$10
      97 01    STAA $0001
      8D 67    BSR $FFB8
      39       RTS

$FF52 8D 74    BSR $FFC8
      C6 0E    LDAB #$0E
      11       CBA
      26 07    BNE $FF60
      86 71    LDAA #$71
      97 07    STAA $0007
      8D 59    BSR $FFB8
      39       RTS

$FF60 C6 0A    LDAB #$0A
      11       CBA
      2A DD    BPL $FF52
      8B 70    ADDA #$70
      97 07    STAA $0007
      8D 4D    BSR $FFB8
      8D 5B    BSR $FFC8
      C6 0E    LDAB #$0E
      11       CBA
      27 3F    BEQ $FFB1
      C6 0A    LDAB #$0A
      11       CBA
      2A F4    BPL $FF6B
      8B 70    ADDA #$70
      D6 07    LDAB $0007
      C0 10    SUBB #$10
      D7 06    STAB $0006
      97 07    STAA $0007
      8D 35    BSR $FFB8
      96 06    LDAA $0006
      8D 31    BSR $FFB8
      8D 3F    BSR $FFC8
      C6 0E    LDAB #$0E
      11       CBA
      27 23    BEQ $FFB1
      C6 0A    LDAB #$0A
      11       CBA
      2A F4    BPL $FF87
      8B 70    ADDA #$70
      36       PSHA
      96 06    LDAA $0006
      80 10    SUBA #$10
      97 05    STAA $0005
      8D 1A    BSR $FFB8
      96 07    LDAA $0007
      80 10    SUBA #$10
      97 06    STAA $0006
      8D 12    BSR $FFB8
      32       PULA
      97 07    STAA $0007
      8D 0D    BSR $FFB8
      8D 1B    BSR $FFC8
      81 0E    CMPA #$0E
      26 F8    BNE $FFA9
      39       RTS

$FFB2 86 0E    LDAA #$0E
      8D 02    BSR $FFB8
      86 2A    LDAA #$2A
$FFB8 B7 C001  STAA $C001
      86 36    LDAA #$36
      8D 02    BSR $FFC1
      86 3E    LDAA #$3E
      B7 C003  STAA $C003
      39       RTS

$FFC5 B6 C001  LDAA $C001
      B6 C003  LDAA $C003
      84 80    ANDA #$80
      27 F9    BEQ $FFC8
      B6 C000  LDAA $C000
      84 0F    ANDA #$0F
      8B E4    ADDA #$E4
      97 09    STAA $0009
      86 FF    LDAA #$FF
      97 08    STAA $0008
      DE 08    LDX $0008
      A6 00    LDAA,X,00
      F6 C001  LDAB $C001
      39       RTS

$FFE4 01       KEYPAD LOOK-UP
      02       TABLE
      03
      0C
      04
      05
      06
      0D
      07
      08
      09
      0B
      00
      0E
      0F
      0A
$FFF4 DE 7E    LDX $007E
      6E 00    JMP,X,00
$FFF8 FF F4    IRQ VECTOR
$FFFA F5 4D    SWI VECTOR
$FFFC F0 E2    RESET VECTOR
$FFFE F0 77    POWER ON VECTOR
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## GUARANTEE

The manufacturers guarantee that, in the even of any defect in workmanship or materials in VELA occurring within twelve months of the date of purchase, they will repair, or at their option, replace the defective part or parts free of charge subject to:

a) The equipment not having been misued, modified or repaired except by a person authorised by the manufacturers.
b) The equipment having been used only on the voltage range specified on VELA.

Users should return the VELA unit in its original packing together with details of when purchased and specific written details of any malfuntion. Users are required to pay postage and it is suggested that the unit is insured whilst in transit.