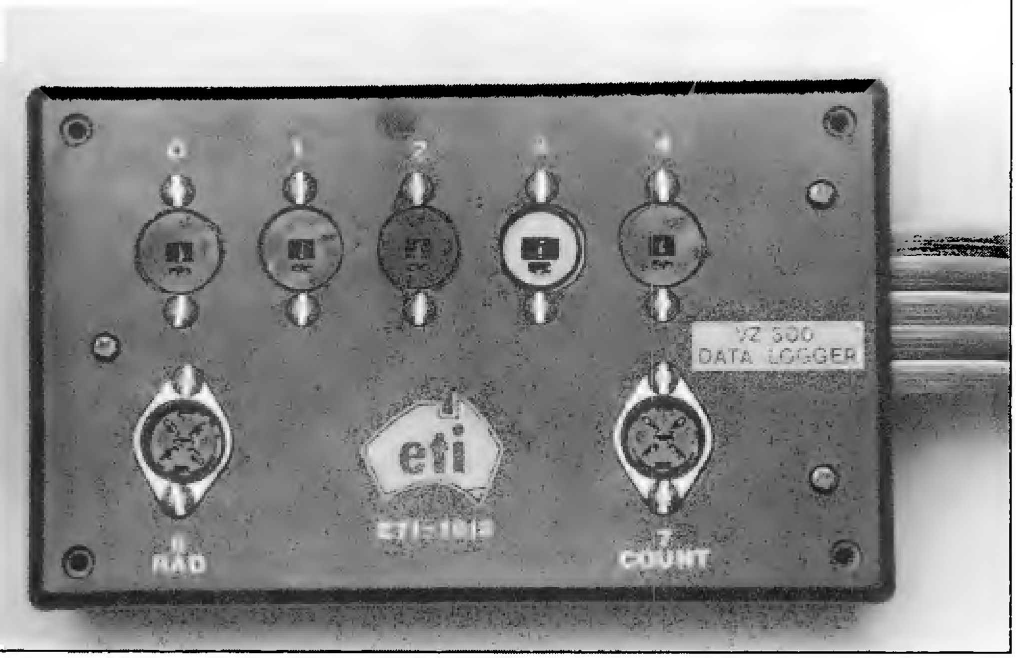
ETI-1612 VZ300 Data Logger

For $60 you can build a box to plug into a VZ300 computer to log up to 8 analogue channels. Data can later be stored on cassette tape.

Bob Sutton



Specifications

Number of channels: 8 analogue (designated 0 through 7).

Channel 7 is used as a counter, being driven from an open collector transistor. Channels to be logged are selected by program.

Voltage Range: +2.5V (count 0) to +3.56V (count 255) with common O V.

Range can be hardware modified to any window in the range 0 to +5V.

Sampling Rate: 3 per second.

This is high enough to count up to 1 pulse per second on channel 7.

Calibration: Transducers are calibrated individually. Every 10 seconds a scan of channels appears on the screen.

Reliability: mainly determined by the reliability of the mains supply.

Power supply: +5V from the VZ300.

Averaging/Counting Interval: 1 hour. This can be changed by program.

Designated RAM Store: 6K bytes. This can be extended; each byte holds one value. 5 channels hours for 51 days fills 6K of RAM.

Digital outputs: There are three digital outputs which could be used for indicators, alarms or control.

THE TASMANIAN BRANCH of the ANZ Solar Energy Society needed a cheap means of recording temperatures and other variables in passively heated solar houses. About 10 days of hourly recording are required to be sure of getting the thermal thumbprint for a house. I thought of designing a battery-powered data logger around the Motorola MC146805 microprocessor but decided instead it would be faster to build an attachment for a cheap, mains-powered microcomputer and to program it in a high level language. Having recently taken a course on the Z-80 microprocessor with Scott Ashton at Elizabeth College I chose the Z-80 based VZ300 which sells for around $120. Of course a TV screen or monitor plus a cassette recorder are also needed. (This is not the first time a VZ has been used as a data logger: Bruce Baudinet of Sunspot Design built one for the VZ200.)

This article gives sufficient detail to build the box (called the "logger") to collect data, to store the data on cassette tape, to retrieve it and to plot a graph. As examples the logger and programs are for the configuration I use for solar work. The programs deliberately lack refinements so that someone literate in BASIC can modify them readily to suit other requirements. Examples of sensors/transducers and their interfacing are given.

I/O Operation

The VZ300 can transfer data from/to up to 256 input/output ports using the INP and OUT instructions. Data is transferred under the control of the $\overline{RD}$, $\overline{WR}$ and $\overline{IORQ}$ lines. I have designated the logger to be the vacant port 64. Thus the code Z=INP(64) transfers one byte (8 bits) of data from port 64 to the real variable Z. Likewise OUT 64,Y transfers Y to the logger output latch. Y can be a constant, a real variable, an integer variable or an

Table 1: A/D control
Lower case letters are used to avoid confusion with the VZ300 lines

$\overline{wr}$	$\overline{rd}$	
1	1	dormant
1	0	offer converted
0	1	start conversion
0	0	forbidden

Table 2: VZ300 output port configuration showing start conversion and offer value instructions for channel 2.

spare	A/D	select	
7 6 5	4 3	2 1 0	LSB
	$\overline{wr}$ $\overline{rd}$	a1 a1 a0	
0 0 0	0 1	0 1 0	start conv= 8+2=19=OAH
0 0 0	1 0	0 1 0	offer value= 16+2=18= 12H

expression but it must be an integer in the range 0 to 255.

The latch (IC2) is used to select the analogue channel (lowest 3 bits) and to control the A/D converter (next 2 bits). The highest 3 bits are spare and their contents are irrelevant.

The five steps to collect a sample are:
1. SELECT the analogue input channel;
2. START the A/D conversion;
3. WAIT for completion;
4. OFFER the converted value to the VZ300;
5. INPUT to VZ300.

OFFER and SELECT can be combined when treating channels sequentially. Table 1 gives the A/D control and Table 2 gives an example of the START and OFFER patterns. Programs 1, 2 and 3 are suitable for testing.

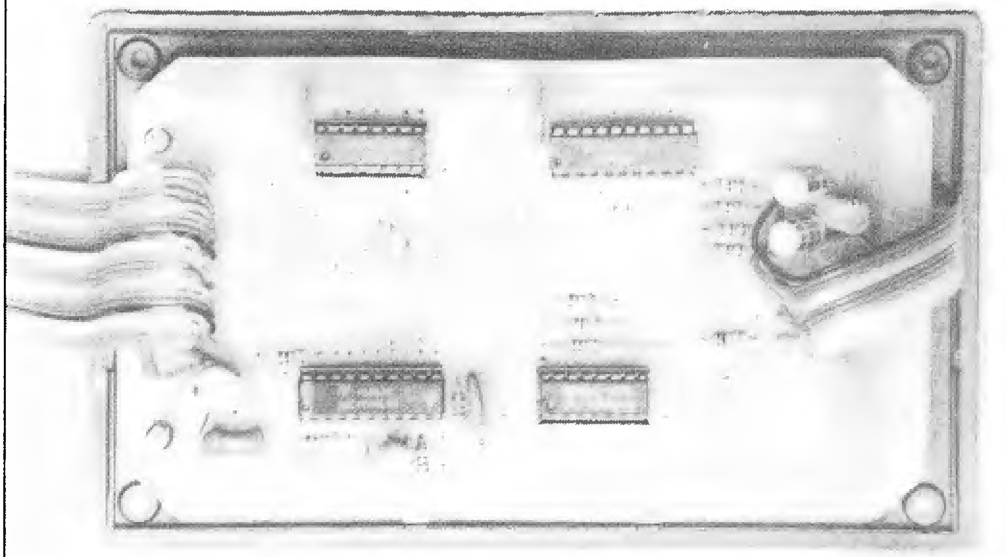
Cassette Data Storage

The collection program (see box) POKEs data into a 6 K block of unused memory. This data is then stored on cassette tape by making the operating system think it is storing a program. Later the data is recovered by the reverse procedure and then some data processing program is loaded and run.

The following is the procedure to be followed to store and recover all 6 K. The modification for reduced storage is given later.
1. Load and run Program 4.
2. Terminate it at the end of logging by CTRL/BREAK.
3. Then type the following instructions, terminating each with RETURN.

```
POKE 30884,254
POKE 30885,143
POKE 30969,0
POKE 30970,168
```

4. CSAVE"datname" having started the tape recorder before RETURN. 5. Choose your own "datname".



Converting to VZ200 operation

With only program modifications the logger will work with the earlier VZ200. The VZ200 has a 3.58 MHz clock, compared with the VZ300 at 3.54 MHz. Therefore some adjustments may be desired in lines 430 and 470 of Program 4.

The main difference lies in the available storage. The VZ200 has a 6K RAM whereas the VZ300 has 16K. With the following changes the VZ200 will run a program as large as Program 4 in conjunction with a 2K data store:

```
Program 4: in line 330 put −31232
           in line 840 put −29184
Immediate POKES: POKE 30884,254
                 POKE 30885,133
                 POKE 30969,0
                 POKE 30970,142
Program 5: in line 30 put 2048 twice
           in line 40 put −31232
Program 6: in line 70 put −31232
```

Continue reading this section only if you want to run large processing programs or if you require more than 2K of data store. Refer to the memory maps starting at the RAM. In both computers the program extends above location 31465, first with the BASIC code and then the numeric variables. String variables and the "stacks" extend downwards from the top of store. The spaces between are free for data storage. I started the VZ200 store at location 34304 = 8600H. For POKE and PEEK instructions the locations above 32767 (= 32K −1) are addressed using negative integers (64K being zero). For example 34304 = -31232. You can search for free space by typing NEW and then using something like Program 5.

As checks of the extents of program and variables it is useful to examine the contents of the address pointers. These two-byte pairs contain the relevant addresses, always starting with the low order byte. For example the BASIC program starts at location 31465 = 7AE9H. Thus from the list of pointers 30884 contains 233=E9H and 30885 contains 122=7AH; this may be verified using PEEKs. At startup, before any program has been entered, the end-of-basic is just two bytes further on at 31467. As program is loaded the end-of-basic advances.

Pointers	Hex	Decimal
End of stack (= start of strings)	78A0/1	30880/1
Start of dimensioned variables	78FB/C	30971/2
End of BASIC	78F9/A	30969/70
Start of BASIC	78A4/5	30884/5

The VZ300 is supplied with a 12V battery eliminator instead of a 9V one. The extra voltage drop tends to overheat the VZ300 voltage regulator. With the extra current drawn by the logger this situation is made worse. A high wattage series resistor may fix this. Instead I used a slightly underrated 9V battery eliminator and initially got random variations in A/D conversions due to 100 pps negative bumps on the 5V rail. A capacitor across the 9V leads cured this.

6. Switch the computer off and then on again before reloading data.
7. To reload data and process
   switch on
   CLOAD"datname"
   NEW
   CLOAD"processprog"
   RUN
   To store less than 6 K, change the 168 in POKE 30970,168 above, to 144 + the number of blocks of 256 bytes (including partly filled blocks). For example if 5 channels were logged hourly for 190 hours then there would be 950 bytes and therefore 4 blocks would be required. Thus the number would be 148 instead of 168.

Analogue Circuits

The ADC0804 A/D converter features span adjustment and high impedance differential input. The inputs have diode clamps which with high source resistance hold the input voltages in the required range of −0.3 V to +5.3 V.

The span control Vref/2 at pin 9 appears from the outside as a 2.5 V source in series with about 1000 ohms. External resistors are added to alter the pin 9 voltage. The span is twice the voltage at pin 9.

The converted count is given by
$C = (V^- - V^-) \times 128 / \text{Vpin } 9$
For example when $V^+= +3.1$, $V^-= +2.5$ and Vpin9 = Vref/2 = 0.5, the count is 153. Out-of-range inputs give counts of 0 or 255.

Transducers

For temperature measurement I mostly use the LM335 sensor. Provided it passes at least 0.5 mA it behaves as a temperature controlled zener diode. The constant is nominally 10 mV/K. Thus at 0°C (=273.2 K) the nominal voltage is 2.73 V and at 30°C it is 3.03 V. The board has

Program 1: I/O Selector Test

To pulse low pin 11 of 74LS138

```
10 Y=INP(64)
20 GO TO 10
40 FOR I=ITO 200:NEXTI
50 GO TO 20
```

Program 2 Output Latch Test

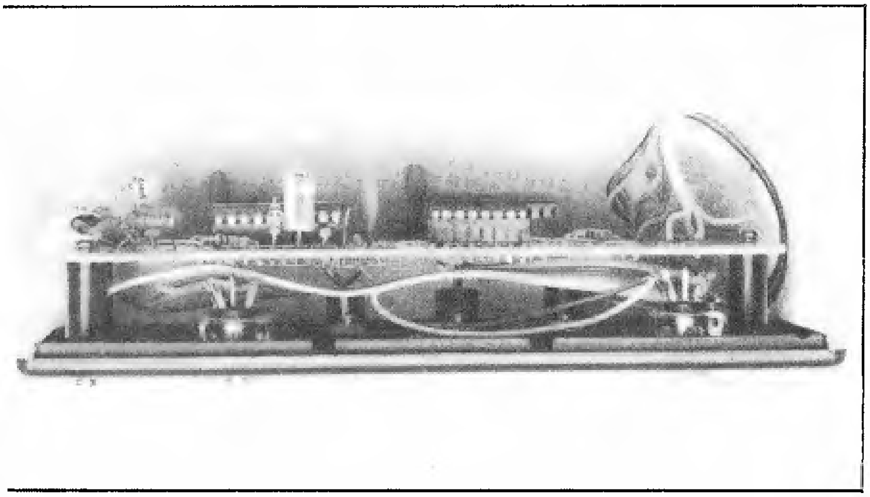
To continually output the number A% to the latch. The lowest 3 bits select the analogue inputs. Pin 13 of 74LS138 pulses low.

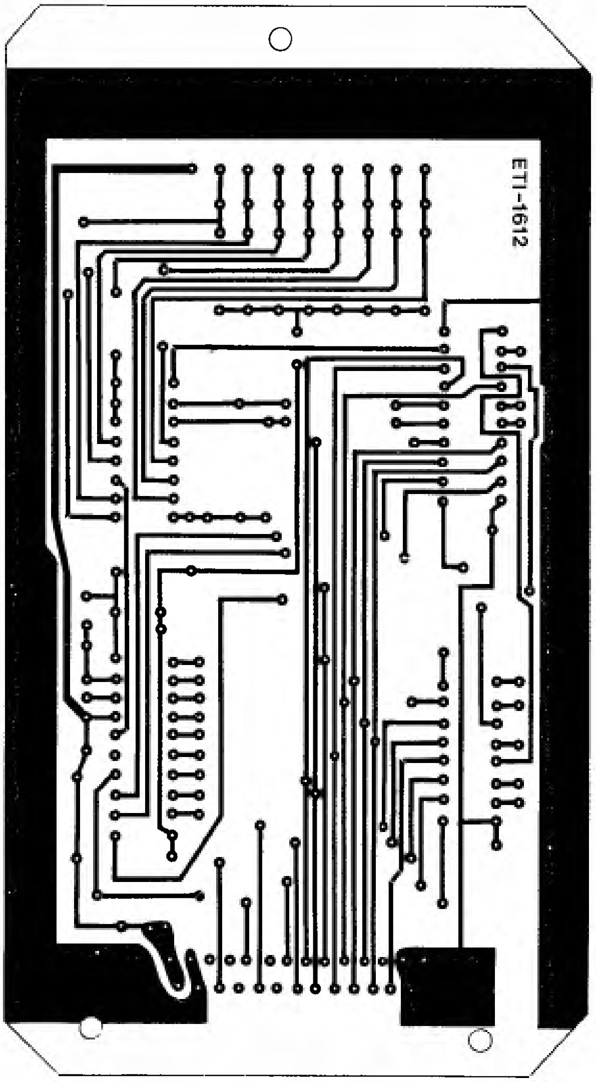
```
10 INPUT"INTEGER IN RANGE 0 TO
255";A%
20 OUT 64,A%
30 REM OPTIONAL DELAY
```

PROGRAM 3 SINGLE CHANNEL DISPLAY

To display a channel (0 to 7)

```
10 INPUT"CHN NUM";A%
20 OUT 64,24+A%     select channel
30 OUT 64,8+A%      start conversion
40 D=INP(64)        delay
50 OUT 64,16+A%     offer convtd value
60 PRINT INP(64)    input & print
70 GO TO 30
```






```
PROGRAM 5    VIEW DATA
This processing program just displays on the screen the raw values
retrieved from cassette tape.
10 INPUT"NUM OF PERIODS";N
20 INPUT"NUM OF ACTIVE CHNS";M
30 IF N*M>6144 THEN N=INT(6144/M)
40 AP=-28672
50 FOR I=1TO N
60 PRINT I;
70 FOR J=1TO M
80 PRINT USING" ###";PEEK(AP)
90 AP=AP+1
100 NEXT J
110 PRINT
120 NEXT I
PROGRAM 6   PLOT DATA
10 CLS:MODE(1):COLOR 4
20 FOR Y=0TO50:SET(10,57-Y):NEXTY
30 FOR Y=0TO50STEP5:SET(11,57-Y):NEXTY
40FORY=0TO50:SET(107,57-Y):NEXTY
50FORY=0TO50STEP5:SET(106,57-Y):NEXTY
60FORX=10TO107:SET(X,57):NEXTX
70AP=-28672
100FORI=101TO150
110YO=PEEK(AP+2*I-2)
120YO=INT(.34*YO+10.2+.5)
130COLOR 4:SET(10+I,57-YO)
140Y1=PEEK(AP+2*I-1)
150Y1=INT(.31*Y1+8.4+.5)
160COLOR 2:SET(10+I,57-Y1)
190NEXTI
200GOTO200
This is broken by CTRL/BREAK
```

Program listings
All the program listed in this article are available on tape from: Tasmanian Branch ANZ5S5, PO Box 121, Sandy Bay, Tas 7005. Send $10 plus stamped self-addressed envelope.

provision for pullup(/down) resistors and filter capacitors.

My photovoltaic solar radiation transducer gives about 300 mV full output which is quite compatible with the span for the LM335. The negative wire is simply joined to V^- and kept well insulated.

I measure electricity consumption by detecting the mark on the rotating disc of a kWh meter. This is done using a reflective opto switch (RS stock No. 307-913) costing about $15. The instrument has LEDs to indicate status to assist in aligning it on the glass in front of the disc. Rubber bands and self adhesive picture hooks are convenient for attachment. A 0.5 second pulse lengthener is required to ensure that a pulse is not missed when the disc is rotating quickly. The program counts pulses by detecting low-to-high transitions for channel 7. Because the IR LED alone draws 40 mA this instrument should be connected to other than the VZ300 +5 V supply.

Graphs

The VZ300 has two graphics modes: MODE (0) for text — 32 characters wide by 16 down (the default mode) and MODE (1) which is 128 x 64. The rectangle is the only symbol in MODE (1) but variation can be obtained by altering the shading.

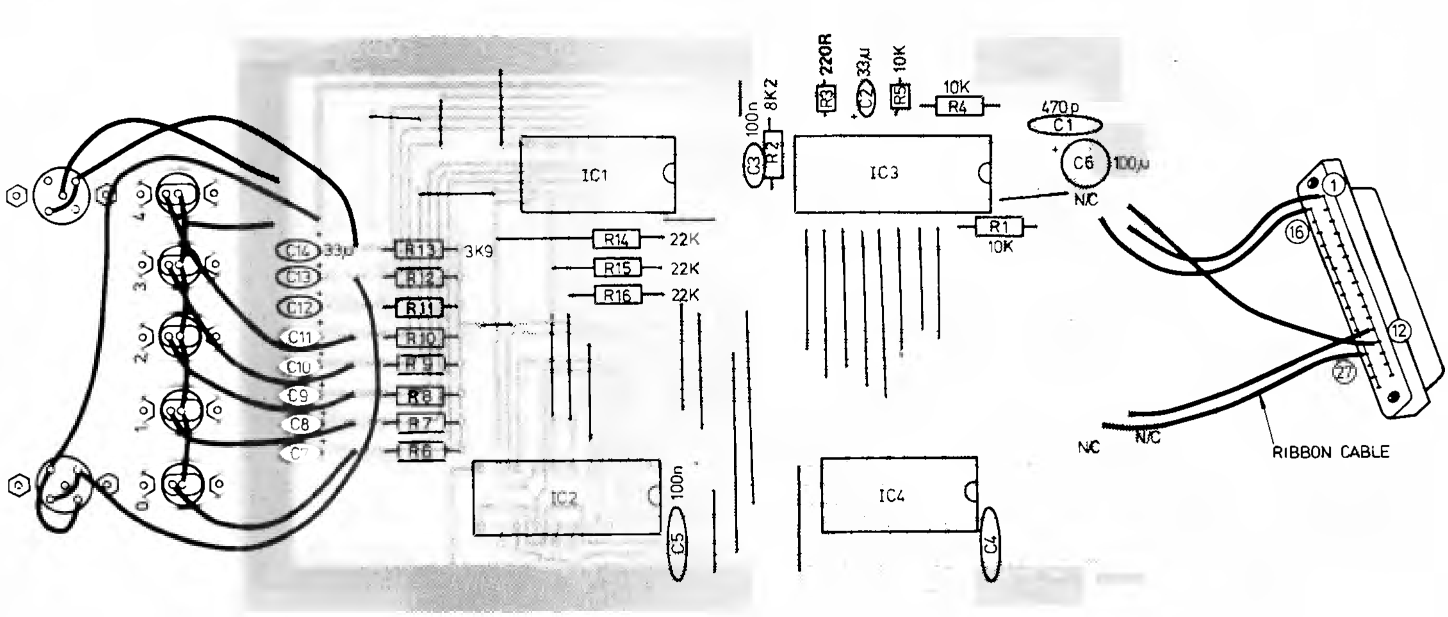
The SET(X,Y) instruction in MODE

Program 4 COLLECTION PROGRAM

```
DATA COLLECTION

10 PRINT"DATA COLLECTION PROGRAM"
20 PRINT
30 DIM A(7),B(7),C$(7),L%(7),S(7)
100 REM INITIATE CONSTANTS, TIME, DATE
110 PRINT"CHANNELS"
120 PRINT"   SLOPE OFFSET IDENT"
130 FOR I=0TO7
140 READ A(I),B(I),C$(I)
150 PRINT USING"  ###.##";A(I);B(I);
151 PRINT C$(I)
160 NEXT I
170 PRINT"IF WRONG THEN BREAK & CHANGE";
171 PRINT" LINES 200-270"
180 PRINT"WRITE DOWN CORRECTED VALUES"
200 DATA 1,0,TEMP
210 DATA 1,0,TEMP
220 DATA 0,0,V
230 DATA 0,0,V
240 DATA 0,0,V
250 DATA 0,0,V
260 DATA 1,0,RAD
270 DATA 1,0,KWH
280 INPUT"NEXT HOUR OF DAY";H
290 INPUT"DAY OF MONTH";D%
300 PRINT"PRESS S TO START LOGGING"
310 A$=INKEY$
320 IF A$<>"S" THEN GO TO 310
330 SH=H:SD%=D%:AP=-28672
335 POKEAP-2,255:POKEAP-1,254

340 IF H<23.5 THEN GO TO 400
350 H=0:D%=D%+1
400 FOR K=1TO360
410 FOR L=1TO30
420 GOSUB600:REM SCAN
430 FOR D=1TO5:NEXT D:REM DELAY
440 NEXT L
450 REM PRINT HOUR & ACTIVE INPUTS
451 GOSUB700
470 FOR D=1TO39:NEXT D:REM FINE DELAY
480 NEXT K
490 REM TRANSFER ACTIVE CHN AVERAGES TO RAM
491 GOSUB800
500 H=H+1
510 GO TO 340

600 REM SUB SCAN
605 OUT64,24
610 FOR I=0TO7
615 OUT64,8+I
620 D=INP(64)
625 OUT64,16+I
630 L%(I)=INP(64)
635 NEXT I
640 FOR I=0TO6
645 S(I)=S(I)+L%(I)
650 NEXT I
655 IF L%(I)>128 THEN NW=1 ELSE NW=0
660 IF NW>OL THEN S(7)=S(7)+1
665 OL=NW:L%(7)=INT(S(7))
670 RETURN

700 REM SUB PRINT LATEST
710 PRINT D%;H;
720 FOR I=0TO7
730 IF C$(I)="V" THEN GO TO 750
740 PRINT L%(I)*A(I)+B(I);
750 NEXT I
760 PRINT
770 RETURN

800 REM SUB STORE
805 FOR I=0TO7
810 IF C$(I)="V" THEN GO TO 860
815 XD=S(I)/10800
820 IF I=7 THEN XD=XD*500
825 X%=INT(XD+.5)
830 IF X%>255 THEN X%=255
835 S(I)=0
840 IF AP>=-20480 THEN STOP
845 POKE AP,X%
850 PRINT X%
855 AP=AP+1
860 NEXT I
865 RETURN
```

The collection program has the following features:

1. **All 8 channels are sampled three times a second. Values from channels 0 through 6 are accumulated to be divided by 10,800 after an hour to give average values. Channel 7 (counter) is accumulated and effectively divided by 21.6 so that it can never overload.**
2. **Each hour, values for active channels are transferred sequentially to storage in RAM starting at address 36864 = 9000H. An active channel is one without a "V" (for vacant) in lines 200 to 270.**
3. **At initialisation the user enters the starting hour (integer 0 through 23) and the day of month. Sampling commences when "S" is pressed. The user determines the significance of the hour eg, period starting, or centered on, or finishing.**
4. **Logging is terminated by CTRL/BREAK or when the store fills. Data for the unfinished hour is lost.**
5. **Day of month is sequential but does not revert to 1 at any change of month.**
6. **Every 10 seconds the screen receives the latest day, hour and scaled values for active channels. This is useful for monitoring and calibrating. Scaling is multiplying by the appropriate constant and adding the offset stored in lines 200 to 270.**



(1) marks the rectangle at the position X (across), Y (down). To get normal plots with Y positive up the variable effectively becomes 63-Y.

Program 6 draws axes and then plots scaled values of data for two channels for time intervals 101 to 150. Lines 120 and 150 contain the appropriate scaling formulae; the +.5 being for correct rounding. A natural improvement would be to store the scaling constants and list of active channels in arrays as in Program 4; but the aim here is to keep it simple.

Construction

Construction is straightforward and only a logic probe is needed for any trouble shooting.

Decide on your input socket layout and then mount suitable polarised sockets on the lid of the box (We used two pin DIN sockets in the prototype.) To minimise crosstalk, keep the common side resistance low in the cable to the board. Also leave the cable long enough to allow the sections to be separated for testing. Solder the passive components — links, capacitors, resistors and IC sockets. Install plenty of test pins. Finally add the 25 way ribbon and 30 way socket to the VZ300 printer port. Solder the only crossover first (socket pin 12); then solder all other pins sequentially (1, 16, 2, 17, . . .). File a depression in the box to hold the ribbon firmly with the box shut. Visually and using an ohm meter check for shorts between adjacent tracks.

Testing

ALWAYS SWITCH OFF THE COMPUTER BEFORE PLUGGING/UNPLUGGING THE LOGGER OR ADDING/REMOVING IC'S.

First, with no logger IC's test that the computer keeps working and that the +5 V reaches all sockets. A logic probe would indicate activity on the address and data lines.

Refer to the section on I/O operation.

Second, insert the I/O selector (74LS138), run Programs 1 and 2 and check separately for low pulses on pins 11 and 13. You will need a logic probe to pick up the pulses. If a logic probe is unavailable then proceed anyway.

Third, insert the data latch (74LS374) and check that it correctly accepts bit patterns from the computer. A voltmeter can be used.

Fourth, taking the usual precautions to earth yourself and the board, inset the analogue selector (CD4051) and test for the output signal at pin 3. Select channels by program via the latch. The analogue inputs have pullup resistors so operation can be checked by earthing inputs.

Fifth, again taking care with earthing, insert the analogue-to-digital converter (ADC0804LCN). Check for oscillator action — pin 4. The analogue voltage reference (pin 7) should be around 2.5 V and the span voltage (pin9) around 0.53 V. Run Program 3 to test the logger. Then proceed to full data collection — Program 4. To display scans more frequently than evey 10 seconds reduce the 30 in line 410. ●

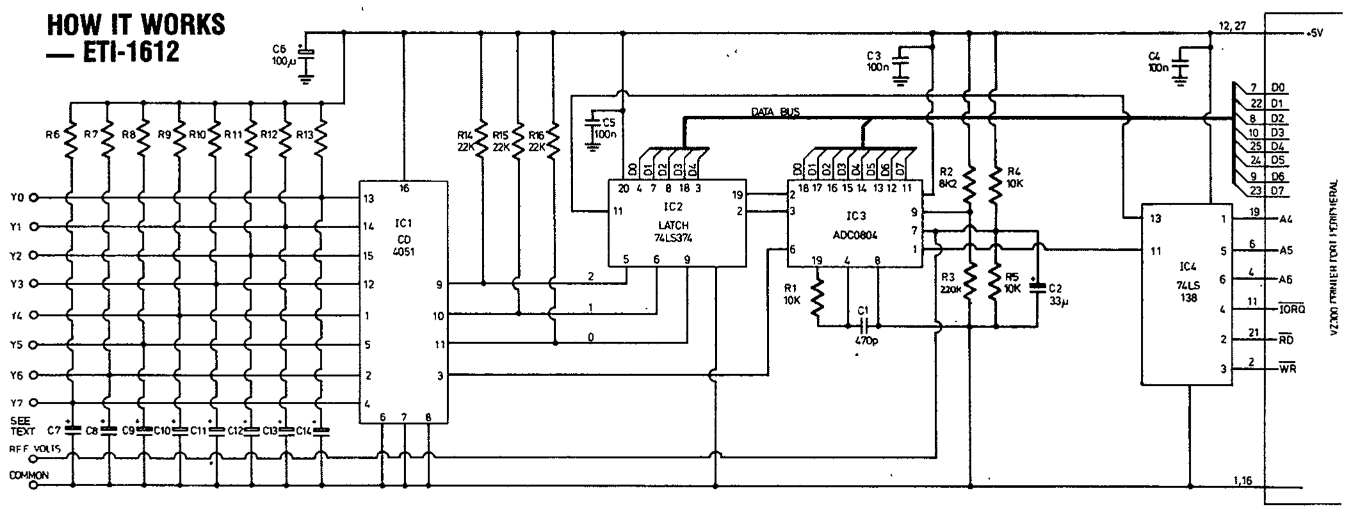
PARTS LIST — ETI-1612

Resistors	All ¼W unless otherwise stated.
R5, R1, R4	10k
R2	8k2
R3	220R
R6-R13	see text
R14, R15, R16	22k
Capacitors	
C1	470p cer
C2	33µ/10V
C3, C4, C5	100n cer
C6, C13	see text
C14	33µ electro
Semiconductors	
IC1	4051
IC2	74LS374
IC3	ADC0804
IC4	74LS138N
IC5	LM335

Miscellaneous

5 x 2 pin Din, 3 x 5 pin Din sockets, ribbon cable, hook-up wire & box.

HOW IT WORKS — ETI-1612



The logger is controlled from the VZ300 output port. Address lines A4 to A6 select the latch IC4, and the read and write lines drives either pin 11 or pin 13 active. These two outputs are connected to either the latch, IC2 or the converter IC3.

Data comes into the input port from one of seven channels in analogue form. The exact form of the transducer responsible for this is up to you. The input port is connected directly to a 4051 which functions as an analogue switch, so that it will take the analogue input and place it on the output pin, pin 3. Notice that space is provided for pull up resistors and capacitors on the input lines (Y0-Y6) which should be matched to the transducer. With an LM 335 temperature sensor, a 3.9 k resistor and 33µ capacitor are appropriate.

Which channel is selected depends on the configuration of pins 9, 10 and 11 on IC1. These are derived from IC2, which loads from the VZ 300 data bus when pin 11 is activated by IC4.

the ADC (pin 6, IC3). The ADC is controlled by pins 1, 2 and 3 and eventually the 8 bit converted value is transferred to the VZ 300 data bus, where it is read by the computer. R4, R5 and C2 set up the reference voltage for the ADC, and R2, R3 set the span. R1 and C1 trim the internal oscillator. Note that the reference voltage is available to the external world via the channel seven socket.