HYTEC ELECTRONICS LTD

5 Cradock Road, Reading, Berkshire, RG2 0JT, U.K.
Tel: +44 (0) 118 9757770 Fax: +44 (0) 118 9757566
Email: sales@hytec-electronics.co.uk
VAT Reg No. 285 2479 27 Web Site: www.hytec-electronics.co.uk

User Manual and Parts List

DAC 670 MK5 CAMAC OPTO ISOLATED DUAL 18 BIT DAC

(18 Bit Binary Resolution - 18 Bit Absolute Accuracy)

Also at 64, Amy Street, Leicester, LE3 2FB, U.K. **(Sales & Service - North)**

Directors: R.R.T.Tatham, G.S.Cross, Secretary: R.R.Tatham
Registered Office: 5, Cradock Road, Reading, Berkshire, RG2 0JT Incorporated in England No. 1246940

DAC 670 MK5 CAMAC OPTO ISOLATED DUAL 18 BIT

(18 Bit Binary Resolution - 18 Bit Absolute Accuracy)

DESCRIPTION

Overview

The 670 Mk5 is high precision Dual 18 bit optically isolated Digital to Analog Converter (DAC), designed to be used as a accurate voltage source or as the "fine trim" on a high voltage system, such as the focus control on an electron microscope. It may also be used to provide very accurate ramp voltages to test ADC systems. General applications include Automatic test equipment, scientific instrumentation, beam positioners and very high quality digital audio.

Description

It is a single width CAMAC module, which contains two completely separate opto-isolated 18 bit DACs.

Each converter circuit includes facilities such as references and power regulators so as to make them totally separate be truly Isolated the module needs to be powered by two transformer isolated, + 21 - 30 Volt

stabilised power supplies, connected via the two 37 way Cannon sockets. However, the CAMAC power supplies may be selected, if desired, at the loss of isolation.

The data for the DAC is stored in to counting registers formed from parallel data entry up/down synchronous counters.

These counting registers may be loaded, incremented or decremented and read via CAMAC Command.

In addition, four optically isolated digital inputs allow either register to be incremented or decremented via the front panel.

Each time the data stored in the DAC data register is altered an automatic micro sequence is started that transfers the data from the register into the main DAC in such a way as to minimise transmission glitches from the analog output.

This circuit also triggers a monostable multivibrator that is used to drive an opto isolator to provide a digital output signal for each DAC for the whole time the Analog value from the DAC is in transition, changing from one value to the next. This is very useful when testing ADCs to know when the output is not 'True'.

The data from the data registers is passed through opto- isolators and fed into the two separate hybrid laser trimmed DAC chips which contain data latches and current to voltage amplifiers.

The Analogue output is passed in voltage form from the DAC outputs into a precision power amplifier working at unity gain. This has been included so that a fully sensing four wire output system can be provided, together with allowing high output currents without self-heating effects on the DACs.

As can readily be seen to get near 18 bit performance over any reasonable length of output lines, a fully sensing circuit is necessary. Consider the case, when used on +10V full scale 1 LSB bit is about 38 uV. A 30 m ohms wire and connector resistance with a 5 mA load would give a 150 uV error, 4 bits.

To help get over these problems. The output amplifier has two stages. The first is a very temperature stable and low noise high gain operational amplifier within the DAC chip, with a + 5mA drive capability. The second is a high power unity gain power driver. A wire link allows the first amplifier alone to be used for low current work and the power buffer together with the precision amplifier for high power work. In either case a fully symmetrical differential amplifier circuit is used. Precision temperature matched resistor networks inside the DAC chip have been employed so as to give peak performance. The power output driver amplifier is capable of providing + 50mA.

There are two output options where sense links must be fitted, but only one set at a time, i.e. if Lemo output is used fit links at the far end of the Lemo cable, if the 37 way Cannon output is chosen then the links will be at its far end. Note: the 37 way plug must always be used to give the analog power inputs.

A test socket is supplied with each unit, just to get it going. It does not give isolated outputs but does power up the system. (Try to minimize the output current used to avoid heating up the module).

The DACs have four programmable signal ranges, which may be selected via CAMAC Commands. (F30 Ax Bit sets) The first two are Unipolar 0V to 10V and 0V to 5V, if the output is being externally powered by floating supplies, this may be referenced so as to be 0 to +10V or 0 to -10V etc, It is coded in straight binary. The second two ranges are + 10V and + 5V coded in 2's Compliment binary. (Bit 18 MSB). Other types of coding may wire linked, see the circuit diagram for details.

As two separate multiturn trim components are used for each range, there is no change in setup, between ranges, however, due to the use of relays, there is a delay time of up to 10 mS between goings from one output range to the other. This delay is only present when going from Range to Range not value to value!

SPECIFICATION

Analog Output

Full 4 wire Sense Circuit

Mode A + 5 mA Output Current all Ranges

Mode B $\pm$ 50 mA Output Current all Ranges (standard)

Note: one pair (only) of sense links must be made externally to the unit, either via the Lemo or 37 way Cannon socket. If not fitted uncontrolled voltages, up + 15 V may come from the outputs.

Setting Time

10V step	45 uS	+1/2 LSB (= 0.00019 %) of final value
LSB change	6 uS	+1/2 LSB (= 0.00019 %) of final value
	(Glitch energy is 500 mV x 500nS for major carry)	

Output Noise

Band Width	0 - 100KHz	60 uV RMS Bipolar
		20 uV RMS Unipolar

Temperature Coefficients

Gain + 5 ppm of FSR /oC max. (5 C - 40 C)
Offset + 1 ppm of FSR /oC max. (5 C - 40 C)

Voltage Range

Software Set

See Chart for details.

NOMINAL OUTPUT VOLTAGE VALUES
0.00000 V to +9.99996 V
0.00000 V to +4.99998 V
-10.00000 V to +9.999924 V
-5.00000 V to +4.999962 V

Isolation voltage
500 Volts peak to peak max. Normal Working voltage + 250 V peak to peak.

Note: Due to the packing density used in the module it is not to be used to isolate Mains voltages etc. If it is used in a High voltage system always put it at the low voltage end of the circuit, and please take all safety precautions.

Output Accuracy
True 18 bit absolute accuracy at 20oC ambient. (After 20 min warm-up).
No missing Code 0oC-50oC.

Isolated Digital Output (set via F30/F28 functions)
4 Per DAC
OFF state 0 - 30 V on sink 5 mA at 0.5 V
DAC output stable pulse output unstable signal
TTL signal isolated to the DAC in question supply. Low = 1 (DAC in transition)
Sinks 8 loads

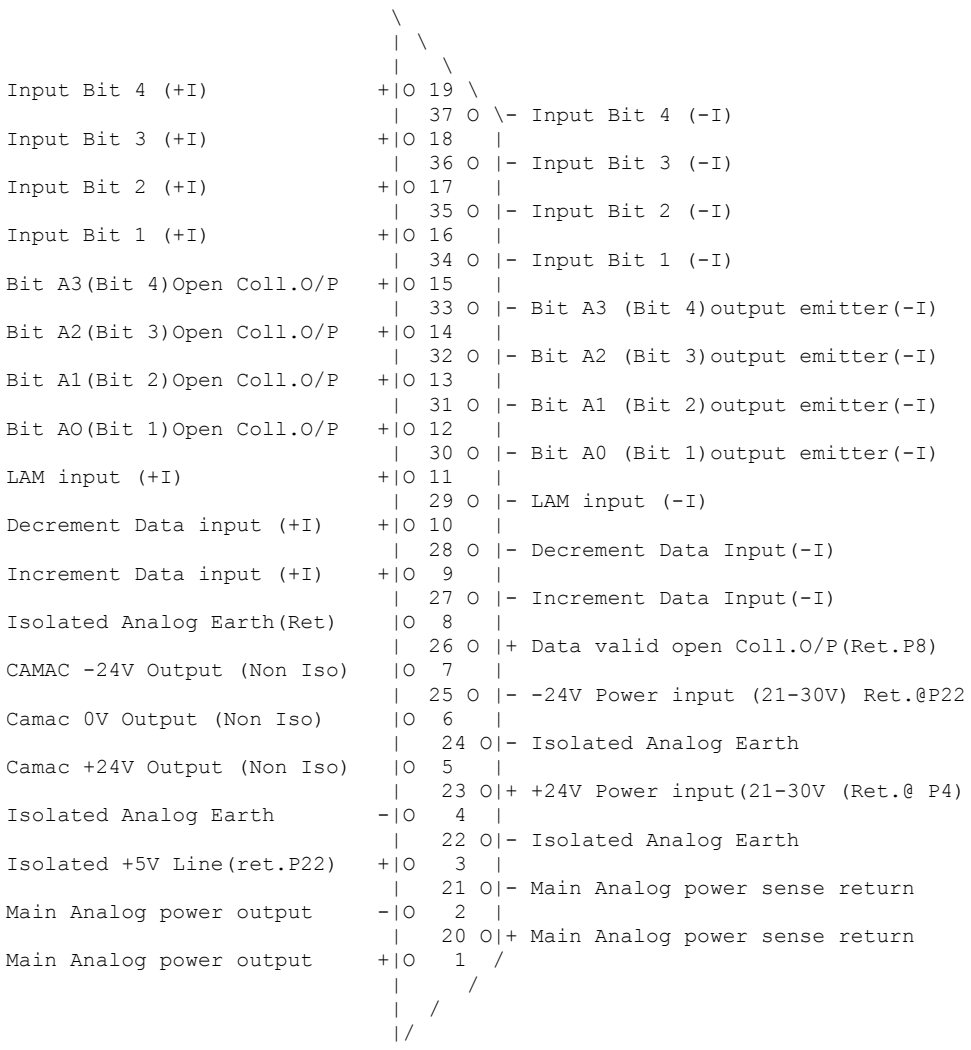
Isolated Digital Inputs
4 per DAC
Input TTL compatible 0 - 1 mA = logic "0"
8 - 20 mA = logic "1"

Reverse diode protected, current limited by 270 ohms resistor.
Normally the + end is taken to +5 V and - end to the TTL output.

Isolated Digital Control Inputs

Increment DAC (if enabled)
Decrement DAC (if enabled)
Set DAC LAM (if selected by wire link option)
0 - 1 mA = logic "0"
8 - 20 mA = logic "1"

"D" TYPE PLUG



AS VIEWED FROM FRONT OF MODULE (MK2 upside down)

Notes

+I shows a current input paired to -I, normally driven by 10mA at 3V.
(21-30V) + The floating stabilised input voltage range.

Open Coll. + Open Collector transistor, collector, (NPN transistor).
@PX = PL1/2 Pin Number X
O/P = Output
Ret. = Return
Non Iso. = Non Isolated.

670 MK2 FUNCTION CODES

F0 A0 Read DAC 'A' Counting Register, gives 18 bits of data, gives 'X' and 'Q'. (Note if LK3 and LK4 are made then 20 bit data is possible).

F0 A1 Read the DAC 'B' Counting Register, gives 18 bits of data, gives 'X' and 'Q'.

F0 A2 Read the opto-isolated digital data inputs, data field 8 bits. Bits 1-4 are from DAC 'A' input socket. Bits 5-8 are from DAC 'B' input socket. Both sockets are 37 way Cannons, gives 'X'.

See the 670 Control data Chart for both F0 A2 and F0 A3.

F0 A3 Read the state of the bit set control lines, 16 bit data field, gives 'X' .Note: Data Read back bits are Sub address plus 1.

Bits 1-4 are opto isolated data output lines for DAC 'A' (via PL1).

Bits 5-8 are opto isolated data output lines for DAC 'B' (via (PL2).

Bits 9-12 are control bits for DAC 'A' (See F28 and F30 for details)

Bits 13-16 are control bits for DAC 'B' (See F28 and F30 for details)

Bits 1-4 may be used as desired by the program.

Bits 5-8 may be used as desired by the program.

Bit 9 is used by DAC A to control Unipolar or Bipolar operation
"0"= Unipolar, "1"= Bipolar.See table for detail.

Bit 10 when set to "1" enables the front panel increment of DAC 'A'.

Bit 11 when set to "1" enables the front panel decrement of DAC 'A'.

Bit 12 is used by DAC A to control its output range,"0"= 0V - 10V or + 10V. "1" = 0V -5V or + 5V. See table for detail.

Bit 13 is used DAC B to control Unipolar or Bipolar operation "0" = 0V - 10V or 0V - 5V, "1" = + 10V or + 5V.

Bit 14 when set to"1" enables the front panel increment of DAC 'B'.

Bit 15 when set to "1", enables the front panel decrement of DAC 'B'.

Bit 16 is used by DAC B to control its output range,
"0"= 0 - 10V or + 10V. "1" = 0 - 5V or + 5V operation. See table for details.

F2	A0	Read and Clear DAC 'A' Counting Registers, 18 bits of data gives 'X' and 'Q' (Note: Data field may be extended to 20 bits via LK3 and 4).
F2	A1	Read and Clear DAC 'B' Counting Registers, 18 bits of data gives 'X' and 'Q' (Note: Data field may be extended to 20 bits via LK3 and 4).
F2	A3	Read and Clear DAC 'A' Counting Registers, also clear DAC 'B' LAM, gives 'X' and 'Q'.
F8	A0	Test LAM, 'Q' = DAC 'A' LAM set and enabled, gives 'X'.
F8	A1	Test LAM, 'Q' = DAC 'A' LAM set and enabled, gives 'X' .
F8	A15	Test all LAM's in the module, 'Q' = DAC 'A' or 'B' LAM set, gives 'X'.
F9	A0	Clear DAC 'A' Counting Register, gives 'X'.
F9	A1	Clear DAC 'B' Counting Register, gives 'X'.
F9	A2	Clear all 16 bit set lines to zero, gives 'X'.
F9	A15	Clear both DAC 'A' and 'B' Counting Registers, Clear and disable all LAM's same action as ZS2 on Dataway, gives 'X'.
F10	A0	Clear DAC 'A' LAM, gives 'X'.
F10	A15	Clear both DAC 'A' and 'B' LAM's, gives 'X'.
F16	A0	Overwrite the DAC 'A' Counting Register, 18 bit data field, (Note: Data field may be 20 bits if LK3 and LK4 are made) gives 'X' and 'Q'.
F16	A1	Overwrite the DAC 'B' Counting Register, 18 bit data field, (Note: Data field may be 20 bits if LK3 and LK4 are made) gives 'X' and 'Q'.
F16	A2	Overwrite the DAC 'A' Counting Register and clear the DAC 'A' LAM, gives 'X' and 'Q'.
F16	A3	Overwrite the DAC 'B' Counting Register and clear the DAC 'B' LAM, gives 'X' and 'Q'.
F24	A0	Disable DAC 'A' LAM, gives 'X'.
F24	A1	Disable 'B' LAM, gives 'X'.
F24	A15	Disable DAC 'A' and 'B' LAM, gives 'X'.
F25	A0	Increment the DAC 'A' Counting Register by 1, independent of the state of the bit set enable, gives 'X' and 'Q'.
F25	A1	Increment the DAC 'B' Counting Register by 1, independent of the state of the bit set enable, gives 'X' and 'Q'.
F25	A2	Decrement the DAC 'A' Counting Register by 1, independent of the state of the bit set enable, gives 'X' and 'Q'.
F25	A3	Decrement the DAC 'B' Counting Register by 1, independent of the state of the bit set enable, gives 'X' and 'Q'.
F26	A0	Enable DAC 'A' LAM, gives 'X'.
F26	A1	Enable DAC 'B' LAM, gives 'X'.
F26	A15	Enable both 'A' and 'B' LAM's, gives 'X'.

F27 A0 Test the DAC 'A' LAM before enable latch, 'Q' = "1" if LAM set, gives 'X'.

F27 A1 Test the DAC 'B' LAM before enable latch,'Q' = "1" if LAM set, gives 'X'.

F27 A2 Test the DAC 'A' Output is stable, 'Q'= "1" if it is, gives 'X'.

F27 A3 Test the DAC 'B' Output is stable, 'Q' = 1 if it is, gives 'X'.

NOTE: Hytec bit set commands on the 670 are controlled by individual F30 (set) and F28 (clear) commands via sub address, each command gives the "X" response:-
F30 Ax set that bit only, ie F30 A6 sets bit 6, which Reads back via R7.
F28 Ax clears that bit only,ie F28 A6 clears bit set bit 6 and read back R7.
All bits are clear simultaneously by the clear commands F9 A2 and the general clear Z.S2 Also cleared by the power up Clear system.

All F28 & F30 sub address codes 0 - 15 give the "X" response.

F28 A0-A3 'Clear' DAC 'A' Bit set opto outputs via PL1.
F30 A0-3 'Set ' (Read back via F0 A3, A0=Bit 1, A3 = Bit R4 when set) (ie The sub address number plus 1 gives F0 A3 Read back bit number).

F28 A4-A6 'Clear' DAC 'B' Bit set opto output via PL2 (Read back via
F30 A4-A7 'Set' F0 A3, A4 = Bit R5, A7 = Bit R8 when set,)

F28 A8 'Clear' Bit set DAC 'A' Mode. Clear= Unipolar.
F30 A8 'Set' Bipolar. Read back bit R9.
Unipolar coded in straight binary bit 18 MSB.
+ 10V Range coded 2's complement Binary.

F28 A9 'Clear' Front panel increment of the data value in
F30 A9 'Set' DAC 'A's' data Register/Counter via PL1 opto input.
(Read back via F0 A3 bit R10).

F28 A10 'Clear' Set = Enable front panel decrement of the data value in.
F30 A10 'Set' DAC 'A's' data register/ counter, via PL1 opto input. (Read back via F0 A3 bit R11).

F28 A11 'Clear' DAC A Range control, Clear= 0 to 10V or + 10V mode.

F30 A11 'Set' Set= 0 to 5V or + 5V range. Read back via F0 A3 bit R12.

F28 A12 'Clear' Bit set DAC 'B' Mode 'clear' = 0 - 10V or + 10V mode.
F30 A12 'Set' 0 - 10V mode, Straight Binary code Bit 18MSB.
Set = + 10V Range bit, code = 2's complement Binary
(Read back via F0 A3 + 10V =R 13 set).

F28 A13 'Clear' Set = Enable front panel increment of the
F30 A13 'Set' data value in DAC 'B' data register/ counter, via PL2 opto input. (Read back via F0 A3 bit R 14)

F28 A14 'Clear' Set = Enable front panel decrement of the
F30 A14 'set' data value in DAC 'B's' data register/ counter, via PL2 opto input. (Read back via F0 A3 bit 15)

F28 A15 'Clear' DAC B range control bit, clear = 0 to 10V or + 10V.
F30 A15 'Set' Set= 0 to 5V or + 5V range. Read back via F0 A3 bit 16.

670 LINK CHART

(See 670 Circuit Diagram)

LK1	A-C	LAM is set on DAC 'A' by an external Current (5uA) into the opto input pair on PL1 pin 11 (+) and 29 (-). Equivalent circuit 1.6V Zener diode with 270 Ohm Resistor.
LK1	A-B (standard)	LAM is set after a preset time (50uS) after command which has altered the state of the DAC 'A', when the 'New' D.C. value will be true and stable.
LK2	A-C	LAM is set on DAC 'B' by an external Current (5mA) into the opto input pair on PL2 pin 11(+) and 29(-). Equivalent circuit 1.6V Zener diode with 270 Ohm resistor.
LK2	AB (standard)	LAM is set after a preset time (50us) after a command which has altered the state of the DAC 'B', when the 'New' D.C. value will be true and stable.
LK3		Open as standard when closed makes both the Data Register 19 bits long. (Does not do anything extra to the DAC)
LK4		Open as standard when closed makes both Data Registers 20 bits long (given LK3 also closed).
LK5		Open- Special Function Expansion option,not implemented.
LK6	A-C (Standard)	This link adds in the high power (+ 50mA) Driver circuit on DAC 'A'.
LK6	A-B	This mode takes out the High power driver and restricts the available output current to + 5mA, it does improve the Noise performance and reduces the internal temperature rise in the module.
LK7	A-C (Standard)	This Link adds in the High power (+ 50mA) Driver circuit on DAC "B".
LK7	A-B	This mode takes out the High power driver and restricts the available output current to + 5mA, it does improve the noise performance and reduces the internal temperature rise in the module.
Note		Each DAC has links on the internal +5V +18V +15V and -18V & -15V power line, these are for Test purposes and must normally be made. +5V Power has been made available on pin 3 of PL1 and 2 it must be restricted to 50 mA max. to avoid overheating.

Table

Programme Control	DAC A		DAC B	
Output Range	Bit Set		Bit Set	
F30 Ax Sets	A8	A11	A12	A15
F28 Ax Clears	A8	A11	A12	A15
0 to 10 V	0	0	0	0
0 to 5V	0	1	0	1
+10V	1	0	1	0
+5V	1	1	1	1
Read back bit Via F0 A3	R9	R12	R13	R16

Adjustments DAC A (Top of PCB)

				PCB LAYOUT PATTERN		SET UP VOLTAGES	
				A	B	A	B
VR	1	0 - 10V	Gain	VR1	VR2	9.999962 V +	4.999981 V
VR	3	0 - 10V	Offset	VR3	VR4	0.000000 V	0.000000 V
VR	2	0 - 5V	Gain	VR5	VR6	4.999962 V +	9.999924 V
VR	4	0 - 5V	Offset	VR7	VR8	-5.000000 V -	10.000000 V
VR	6	+ 10V	Gain				
VR	8	$\bar{+}$ 10 V	Offset				
VR	5	$\bar{+}$ 5 V	Gain				
VR	7	$\bar{+}$ 5 V	Offset				

Adjustments DAC B. (Bottom of PCB)

				PCB LAYOUT PATTERN		SET UP VOLTAGE	
				A	B	A	B
VR	9	0 - 10V	Gain	VR9	VR10	9.999962 V +	4.999981 V
VR	11	0 - 10V	Offset	VR11	VR12	0.000000 V	0.000000 V
VR	10	0 - 5V	Gain	VR13	VR14	4.999962 V +	9.999924 V
VR	12	0 - 5V	Offset	VR15	VR16	-5.000000 V -	10.000000 V
VR	14	+ 10 V	Gain				
VR	16	$\bar{+}$ 10 V	Offset				
VR	13	$\bar{+}$ 5 V	Gain				
VR	15	$\bar{+}$ 5 V	Offset				

Adjustment Procedures

First let the module warm up for 20 minutes into an equivalent to normal operational load.

Basically, the DAC to be adjusted is switched between 0 and full scale by software and the adjustments are made as follows:-

0-10V range, set VR3 (VR11) to give 0.000000V then set 9.999962V via VR1 (VR9), repeat until both are correct.

0-5V range, set VR4 (VR12) to give 0.000000V then set 4.999981V via VR2 (VR10), repeat until both are correct.

+10V range and +5V range, it will be found the the adjustment potentiometer on each range interact and a strategy of halving the apparent areas on each adjustment together with a lot of patience should produce the correct result with repeated adjustments.

+10V range, set VR8 (VR16) to give -10.000000V then set +9.999924V via VR6 (VR14), repeat until both are correct.

+5V range, set VR7 (VR15) to give -5.000000V then set VR5 (VR13) to give 4.999962V, repeat until both are correct.

PARTS LIST FOR HYTEC 670 MK V

Integrated Circuits

1	SN74LS123N	4		40	SN74LS14N	
2	SN74LS132N	2		41	SN74193N	10
3	SN74LS32N	2		42	SN74193N	
4	SN7414N	5		43	SN74193N	
5	SN7401N	1		44	SN74193N	
6	SN74LS32N			45	SN74193N	
7	SN74LS08N	2		46	N8234B	1
8	N82S100 (P670 P8)	1	(S)	47	SN75452N	1
			S			
			S			
9	SN74LS123N			48	HP2630	5
10	SN74LS123N			49	SN74193N	
11	SN74LS123N			50	SN74193N	
12	SN74LS375N	1		51	SN74193N	
13	SN74LS279N	1		52	SN74193N	
14	SN74S188N(P670/P114)	1	(S)	53	SN74193N	
			S			
			S			
15	SN74S188N(P670/P15)	1	(S)	54	HP2630	
			S			
			S			
16	SN74S188N (P670/P1)6	1	(S)	55	HP2531	
			S			
			S			
17	SN74622N	1		56	HP2531	
18	SN74S244N	6		57	HP2531	
19	SN74S244N			58	HP2531	
20	SN74S244			59	HP2531	
21	F93L34B	2		60	HP2531	
22	F9334B			61	HP2531	
23	ILQ05	2		61	HP2531	
24	ILQ05			63	HP2531	
25	SN74LS132N			64	HP2630	
26	DM8092N	1		65	HP2630	
27	SN74LS08N	1		66	HP2531	
28	SN74LS622N			67	HP2531	
29	SN74LS244N			68	HP2531	
30	SN74LS244N			69	HP2531	
31	SN74LS244N			70	HP2531	
32	SN74S240N	1		71	HP2531	
33	HP2531	23		72	HP2531	
34	HP2531			73	HP2531	
35	HP2531			74	HP2531	
36	HP2531			75	HP2630	
37	SN74LS14N			76	AD1139K *	2
38	SN74LS14N			77	AD1139K *	
39	SN74LS14N			78	BUF634 (on special PCB)	
				79	OP 07C	
				80	BUF634 (on special PCB)	
				81	OP 07C	
				82	SN74S188N (S)	

(S) = socketed
S
S

* = AD1139J for 17 bit units (absolute accuracy) Normal 18 bits.

Voltage Regulations

VReg	1	uA7818C)
VReg	2	uA7918C)
VReg	3	uA7818C) All mounted on the Rear panel
VReg	4	uA7918C) With double mica insulator Kits
VReg	5	uA7815C
VReg	6	uA79L15C
VReg	7	LM2931A T5.0
VReg	8	uA7815C
VReg	9	uA79L15C
VReg	10	LM2931A T5.0

Transistors

TR1	ZTX314	(1)
TR2	2N3903	(6)
TR3	2N3903	
TR4	2N3903	
TR5	2N3903	
TR6	2N3903	
TR7	2N3903	

Diodes

D1	IN5401	1	D17	IN4004
D2	BZY88C3V0	1	D18	IN914
D3	IN914	7	D19	IN4004
D4	IN914		D20	IN914
D5	IN914		D21	IN4004
D6	IN914		D22	IN914
D7	HP5082-2811	4	D23	IS121
D8	HP5082-2811		D24	1S121
D9	HP5082-2811		D25	1S121
D10	HP5082-2811	4	D26	1S121
D11	IN4004		D27	1S121
D12	IN4004 * (fit backwards)		D28	1S121
D13	IN4004		D29	IN4004
D14	IN4004 * (fit backwards)		D30	IN4148
D15	IN4004		D31	IN4148
D16	IN914		D32	IN4148

* = fit back to front not as shown on the ident screen.

Note: 1N4148 or 1N914 or 1N916 may be used,in place of each other.

Resistors - all Mullard MFR25 +1% 50ppm Metal Film

R1	22K	1	R41	270
R2	10K	5	R42	270
R3	220	6	R43	270
R4	27K	1	R44	270
R5	15K	5	R45	270
R6	220		R46	270
R7	1K	8	R47	270
R8	1K		R48	270
R9	1K		R49	270
R10	1K		R50	270
R11	560	6	R51	270
R12	560		R52	270
R13	560		R53	220
R14	560		R54	220
R15	270	44	R55	270
R16	270		R56	270
R17	560		R57	270
R18	560		R58	270

R19	1K		R59	270	
R20	1K		R60	270	
R21	470	2	R61	270	
R22	470		R62	270	
R23	180k	2	R63	270	
R24	180K		R64	270	
R25	10K		R65	270	
R26	15K		R66	270	
R27	10K		R67	270	
R28	4.7K		R68	270	
R29	2.2K	5	R69	270	
R30	1K		R70	270	
R31	1K		R71	270	
R32	15K		R72	270	
R33	270		R73	270	
R34	270		R74	270	
R35	270		R75	220	
R36	270		R76	220	
R37	270		R77	3.3K	
R38	270		R78	20K	
R39	270		R79	41.2K + 0.25% Vishay	
R40	270		R80	41.2K ± 0.25% Vishay	
R81	41.2K + 0.25% Vishay		R101	1K + 2%	
R82	2.15 ± 0.25% Vishay		R102	1K ± 2%	
R83	1M ohm + 5% film (low TC)		R103	51 ± 2%	
R84	15K		R104	68 ± 2%	
R85	15K		R105	68 ± 2%	
R86	1K + 2%		R106	47 2.5W or BZX70 C7V5	
R87	1K		R107	NOT FITTED	
R88	50 + 2%		R108	NOT FITTED	
R89	68 ± 2%		R109	NOT FITTED	
R90	68 ± 2%		R110	NOT FITTED	
R91	47 2.5W or BZX 70 C7V5		R111	NOT FITTED	
R92	3.3K		R112	NOT FITTED	
R93	20K + 2%		R113	NOT FITTED	
R94	41.2K + 0.25% Vishay		R114	NOT FITTED	
R95	41.2K ± 0.25% Vishay		R115	NOT FITTED	
R96	41.2K ± 0.25% Vishay		R116	NOT FITTED	
R97	2K + 0.25% Vishay		R117	100K ohms	
R98	1M ohm + 5% film low TC		R118	820	
R99	Not fitted				
R100	Not fitted				

Resistor Packs (all common power unless noted)

RP1	1K	(9 pin)	4	RP8	2.2K	(10 pin)	4
RP2	1K	(9 pin)		RP9	2.2K	(10 pin)	
RP3	1K	(9 pin)		RP10	3.3K	(10 pin)	
RP4	10K	(10 pin)	1	RP11	3.3K	(10 pin)	
RP5	330	(8 pin 4R's)	2	RP12	560	(9 pin)	
RP6	330	(8 pin 4R's)	2				
RP7	270	(9 pin)					

Variable Resistors

VR1	50K	Muliturn	BOURNS 3262	16
VR2	50K	"	BOURNS 3262	
VR3	50K	"	BOURNS 3262	
VR4	50K	"	BOURNS 3262	
VR5	50K	"	BOURNS 3262	
VR6	50K	"	BOURNS 3262	
VR7	50K	"	BOURNS 3262	
VR8	50K	"	BOURNS 3262	
VR9	50K	"	BOURNS 3262	
VR10	50K	"	BOURNS 3262	
VR11	50K	"	BOURNS 3262	
VR12	50K	"	BOURNS 3262	
VR13	50K	"	BOURNS 3262	
VR14	50K	"	BOURNS 3262	
VR15	50K	"	BOURNS 3262	
VR16	50K	"	BOURNS 3262	

Capacitors

C1	10uF 35V M.C.T	1	C13	330pf 63V Ceramic	
C2	47uF 20V M.C.T	1	C14	330pf 63V Ceramic	
C3	22uF 6V M.C.T	2	C15	820pf +10% 63V Ceramic	2
C4	22uF 6V M.C.T		C16	820pf 63V Ceramic	
C5	330pf 63V Ceramic	3	C17	180pf 63V Ceramic	2
C6	56pf 63V Ceramic	1	C18	220pf 63V Ceramic	
C7	2.2nF +10% 63V Ceramic	6	C19	180pf 63V Ceramic	
C8	2.2nF 63V Ceramic		C20	220pf 63V Ceramic	
C9	2.2nF 63V Ceramic		C21	6.8 MFD +20% 35V Tant Bead	4
C10	2.2nF 63V Ceramic		C22	6.8 MFD ±20% 35V Tant Bead	
C11	2.2nF 63V Ceramic		C23	10 MFD ±20% 25V Tant Bead	12
C12	2.2nF 63V Ceramic		C24	10 MFD ±20% 25V Tant Bead	
C25	15 MFD +20% 16V Tant Bead		C37	6.8 MFD +20% 35V Tant Bead	
C26	15 MFD ±20% 16V Tant Bead		C38	6.8 MFD ±20% 35V Tant Bead	
C27	10 MFD ±20% 25V Tant Bead		C39	10 MFD ±20% 25V Tant Bead	
C28	47 MFD ±20% 6.3V Tant Bead		C40	10 MFD ±20% 25V Tant Bead	
C29	10 MFD ±20% 25V Tant Bead		C41	15 MFD ±20% 16V Tant Bead	
C30	10 MFD ±20% 25V Tant Bead		C42	15 MFD ±20% 16V Tant Bead	
C31	0.1 MFD ±80% -20% 100V Mono Ceramic		C43	10 MFD ±20% 25V Tant Bead	
C32	0.1 MFD +80% -20% 100V Mono Ceramic		C44	47 MFD +20% 6.3V Tant Bead	
C33	10 MFD +20% 25V Tant Bead		C45	10 MFD +20% 25V Tant Bead	
C34	10 MFD ±20% 25V Tant Bead		C46	10 MFD ±20% 25V Tant Bead	
C35	0.1 MFD ±80% -20% 100V Mono Ceramic		C47	0.1 MFD ±80% -20% 100V Mono Ceramic	
C36	0.1 MFD +80% -20% 100V Mono Ceramic		C48	0.1 MFD +80% -20% 100V Mono Ceramic	
C49	10 MFD +20% 25V Tant Bead		C51	0.1 mfd +80% -20% 100V Mono Ceramic	
C50	10 MFD ±20% 25V Tant Bead				
C52	0.1 MFD ±80% -20% 100V Mono Ceramic				

Note: All ceramic Caps. <330 pF are + 2% 63 Volts.

All ceramic Caps. >330 pf but ≤2200 pF are +10% 63V.

MCT = Metal cased Tantalum.

Plugs

PL1 37 Way Cannon 'D' type plug, with female screw lock retention.
PL2 37 Way Cannon 'D' type plug, with female screw lock retention.

Sockets

SK3 4 Pole Lemo RA0304) mating part LEMO F0304NY
SK4 4 Pole Lemo RA0304) " " " "

Relays

RL1)
RL2) Single Pole Change Over Farnell No. 224-480
RL3) (Siemens Part No. V23026-A1001-B201 (5V Coil))
RL4)
RL5) Dual Pole Change Over Farnell No. 177-825
RL6) (Ormron G6H H-2100 (5V Coil))
RL7)
RL8) Single Pole Change Over Farnell No. 224-480
RL9) (Siemens Part No. V23026-A1001-B201)
RL10)
RL11) Dual Pole Change Over Farnell No. 177-825
RL12) (Ormron G6H-2100)

LED

1 off Red 0.2 inch + clip

Chassis Kit

1 off Benney CM 1 Kit (long screen)
1 off Jacking Screw

I.C. Sockets

1 off 28 pin turned pin low profile (IC8)
4 off 16 pin turned pin low profile (IC14-16 and IC82)

Heat Sink
2 off Hytec special of Elantec Power Buffers

Fuses

FS1 1A
FS2 1A
FS3 3A
FS4 0.25A - 0.5A
FS5 0.25A - 0.5A
FS6 0.25A - 0.5A
FS7 0.25A - 0.5A

Fuse Holders

6 off normal
6 off IC socket type

P.C.B.

1 off 670 issue 5
Note : There are wire mods to this PCB, under IC's.