Reference Manual

VL-AOUT-1

10-Bit Analog Output
Card for the STD Bus

STD

VERSALOGIC
CORPORATION

VL-AOUT-1

10-Bit Analog Output Card
for the STD Bus

Model VL-AOUT-1

10-Bit Analog Output Card for the STD Bus

REFERENCE MANUAL

VL-AOUT-1 Rev. 1.00
Doc. Rev. 06/15/94

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MAOUT1

Model STD AOUT-1
Analog Output Card for the STD BUS

REFERENCE MANUAL

TABLE OF CONTENTS

OVERVIEW

The STD AOUT-1 board is a four channel analog output board compatible with the STD BUS. It provides standard 0-10 volt analog output signals with .1% (10 bit) resolution.

Operating Description

Rather than designing the AOUT-1 board with four separate digital to analog (D/A) converter chips, the cost was lowered and the accuracy raised by combining a single precision D/A converter chip with circuitry that holds the desired voltage level at each output channel after the conversion has been completed (i.e. sample and hold). A brief description of the board's operation is provided below.

Although the AOUT-1 board provides four independent channels of analog output, there is only one D/A converter chip on the board. Each of the four output channels includes its own sample and hold circuit, and output buffer. The voltage at the sample and hold circuit of each channel is rewritten every 50us by a single 10 bit D/A converter. This happens continuously, without regard for the activity on the STD BUS.

The value to which each channel is set is stored in an on-board memory which is four channels by 10 bits wide. The 10 bit A/D converter continually accesses this memory to determine what voltage level each channel should currently be set to. The memory array is designed so that both the on-board A/D converter and the STD BUS system processor can access it simultaneously without conflict or delay.

To change a channel's value (i.e. voltage level), the STD BUS processor needs only to write a new binary value into the proper on-board memory cell. Since the system data bus is only 8 bits wide, this is done in two steps. First, the lower 8 bits of the new value are written to the lower of the two I/O ports occupied by the AOUT-1 board. This data does not go into the on-board memory, but is simply stored in an 8 bit latch. Next, the upper two bits of data, plus two bits representing the channel number, are written to the upper I/O port. When this happens the appropriate on-board memory cell is selected, and both the upper two bits of data, and the lower 8 bits that were previously stored in the on-board latch, are simultaneously written into the 10 bit wide memory cell.

Additional circuitry converts the +5 volt input to the required $\pm$15 volts to run the D/A converter and the output buffers, and a power-on reset circuit disables the outputs until the user has initialized the on-board memory.

STD BUS COMPATIBILITY

The STD AOUT-1 board is compatible with 8085, Z80, and 8088 (80188) type systems. It requires only +5V (regulated) power for operation.

When inserting the AOUT-1 board into an STD BUS card cage, be certain that the card ejector (pin 1 edge of the card) is aligned in the same direction as other cards in the system (usually upward). The AOUT-1 board has a key slot cut between pins 25 and 27. It is recommended that a matching key be installed in the STD BUS motherboard connector to prevent the card from being installed upside down.

The STD AOUT-1 board should be inserted or removed from the STD BUS card cage only when the power to the bus is turned off.

STD BUS Pinout

Connections from the AOUT-1 board to the STD BUS are shown below. Pins 1 and 2 are at the top (card ejector) edge of the board. As noted below the odd numbered pins are on the component side of the board while the even numbered pins are on the solder side. Direction of signal flow is referenced to the AOUT-1 board.

COMPONENT SIDE				SOLDER SIDE			
PIN	SIGNAL	FLOW	DESCRIPTION	PIN	SIGNAL	FLOW	DESCRIPTION
1	+5V	In	+5 volt power	2	+5V	In	+5 volt power
3	GND	In	Digital ground	4	GND	In	Digital ground
5	VBB/VBAT	-	-5V or bat. backup	6	-5V	-	-5V power
7	D3	In	Data bus	8	D7	In	Data bus
9	D2	In	Data bus	10	D6	In	Data bus
11	D1	In	Data bus	12	D5	In	Data bus
13	D0	In	Data bus	14	D4	In	Data bus
15	A7	In	Address bus	16	A15	-	Address bus
17	A6	In	Address bus	18	A14	-	Address bus
19	A5	In	Address bus	20	A13	-	Address bus
21	A4	In	Address bus	22	A12	-	Address bus
23	A3	In	Address bus	24	A11	-	Address bus
25	A2	In	Address bus	26	A10	-	Address bus
27	A1	In	Address bus	28	A9	-	Address bus
29	A0	In	Address bus	30	A8	-	Address bus
31	WR*	In	Write strobe	32	RD*	-	Read strobe
33	IORQ*	In	I/O addr. select	34	MEMRQ*	-	Memory addr. select
35	IOEXP*	In	I/O expansion	36	MEMEX*	-	Memory expansion
37	REFRESH*	-	Refresh timing	38	MCSYNC*	-	Machine cycle sync.
39	STATUS1*	-	CPU status	40	STATUS0*	-	CPU status
41	BUSAK*	-	Bus acknowledge	42	BUSRQ*	-	Bus request
43	INTAK*	-	Interrupt acknowl.	44	INTRQ*	-	Interrupt request
45	WAITRQ*	-	Wait request	46	NMIRQ*	-	Non-maskable interrupt
47	SYSRESET*	In	System reset	48	PBRESET*	-	Push button reset
49	CLOCK*	-	CPU clock	50	CNTRL*	-	AUX timing
51	PCO	-	Priority chain out	52	PCI	-	Priority chain in
53	AUXGND	-	±12 volt ground	54	AUXGND	-	±12 volt ground
55	AUX+V	-	+12 volt input	56	AUX-V	-	-12 volt input

OUTPUT CONNECTION

Analog output signals are connected from the AOUT-1 board using a standard 26 pin socket connector which mates with the on-board header. Standard cable assemblies are available for this purpose from VersaLogic (refer to the VersaLogic STD BUS Series Price List for more information).

When connecting the 26 pin socket to the board, it must be oriented correctly. The "pin 1" end of the connector (red stripe or other marking on the cable) should be installed nearest to the card ejector on the AOUT-1 board.

Output Connector Pinout

The pinout of the output connector is shown below. Connector pin 1 is nearest to the card ejector and farthest from the board edge. Pin 2 is nearest to the card ejector and nearest to the card edge (all even numbered pins are in the same row).

The table below lists the pinouts of the board as originally delivered. The output signals may be re-jumpered to other pins on the output connector (if required) as detailed in the following section.

Connector P1

Pin	Name	
1	CH0	(channel 0 output signal)
3	AGND	
5	CH1	(channel 1 output signal)
6	AGND	
7	CH2	(channel 2 output signal)
9	AGND	
11	CH3	(channel 3 output signal)
12	AGND	
15	AGND	
18	AGND	
21	AGND	
24	AGND	
25	(SENSE)	

Note: Pin numbers not listed are open (no connection). AGND = Analog ground.

Alternate Connector Pinouts

Although the AOUT-1 board will normally be used with the pinout shown above, it may be jumpered for several alternate pinouts as detailed in the table below. These alternate pinouts might be used in several special situations.

When several AOUT-1 boards are being used in a system, it is often convenient to assign different output pins to each board in the system.

This allows all of the AOUT-1 boards to share a single 26 pin cable, "daisy-chained" between them, rather than requiring a separate cable from each board to the external connection. This method can cut cable and connector costs, and simplify system interconnection in some applications.

The pins to which each output signal can be routed are noted below. For example output channel 0 (OUT0) can be jumpered to pin 1, 2, 13 or 14 in the cable.

Connector P1

Pin	Name	Signal
1	CH0**	OUT0
2	CH8	OUT0
3	AGND	
4	CH9	OUT1
5	CH1**	OUT1
6	AGND	
7	CH2**	OUT2
8	CH10	OUT2
9	AGND	
10	CH11	OUT3
11	CH3**	OUT3
12	AGND	
13	CH4	OUT0
14	CH12	OUT0
15	AGND	
16	CH13	OUT1
17	CH5	OUT1
18	AGND	
19	CH6	OUT2
20	CH14	OUT2
21	AGND	
22	CH15	OUT3
23	CH7	OUT3
24	AGND	
25	SENSE	
26	NC	

Note: AGND = Analog ground.
** Signal jumpered to this pin as originally delivered.

Connection to Analog Devices 3B Series

The alternate connector pinouts listed above can also be used when the AOUT-1 board is connected to the Analog Devices 3B Series of signal conditioners. The AOUT-1 pinout, which is identical to the 3B Series pinout, allows a particular channel on the 3B Series backplane to be selected for output conditioning. It also allows the AOUT-1 to be "daisy-chained" on the same cable as other analog boards which are connected to the 3B Series backplane.

An isolated current loop output module is available for 3B Series use.

ADDRESS SELECTION

The AOUT-1 board is an I/O mapped board which occupies two I/O port locations. An on-board ten position switch (labeled "Address") is used to select the I/O address of the board. The table below shows the ten possible address selections and the resulting locations of the two I/O ports.

Switch Setting	Location (Hex)	Location (Decimal)
0	00-01	00-01
1	10-11	16-17
2	20-21	32-33
3	30-31	48-49
4	40-41	64-65
5	50-51	80-81
6	60-61	96-97
7	70-71	112-113
8	80-81	128-129
9	90-91	144-145

Addressing of the AOUT-1 board is also controlled by the "A1", "A2", "A3", and "IOX" jumpers. The "A1", "A2", and "A3" jumpers allow the board to be located at 70 additional port locations if necessary. The "IOX" jumper allows the AOUT-1 board to be located in the extended (or "secondary") I/O map rather than the normal one. These pads should only be jumpered for special applications. See Jumper Options for more information.

SOFTWARE INTERFACE

The AOUT-1 board is operated thru two system I/O ports. The two data ports are used to write 10 bits of binary data, plus two channel select bits to the board.

Input Values

Each of the AOUT-1 channels outputs a voltage according to the 10 bit binary value written to that channel. This allows the output to be adjusted in 1,023 steps (0 thru 1023). The actual output voltage is dependent on both the value that is written to a channel, and the current calibration of the board.

As delivered, the board is precalibrated for the normal output of .01 volt (10mv) per step. This corresponds to a maximum output (span) of 10.23 volts (dividing 10.23 volts by 1023 steps results in .01 volts per step). This output span is quite easy to use since decimal values correspond directly to an output voltage (535 = 5.35 volts, etc). The relationship of input values to output voltages is shown in the examples below.

Decimal Value =	Hex Value =	Output Voltage
0	0	0.00
1	1	0.01
2	2	0.02
10	A	0.10
12	C	0.12
100	64	1.00
325	145	3.25
500	1F4	5.00
801	321	8.01
1000	3E8	10.00
1023	3FF	10.23

If desired, the board can be recalibrated for a slightly different span (maximum output voltage), but whatever value is selected will be divided into 1,023 steps. See the Calibration section for more information.

Data Ports

The board's two I/O ports are referred to as "low" (lower address) and "high" (higher address) data ports. The significance of the bits written to these ports is as follows:

```
7  6  5  4  3  2  1  0
|  |  |  |  |  |  |  |
|__|__|__|__|__|__|__|___Data Bits 0-7
```

Low Byte Data Port (board address + 0)

```
                7  6  5  4  3  2  1  0
Disable   ___|        |  |        |  |
Channel #  _______|__|        |__|___Data Bits 8-9
```

High Byte Data Port (board address + 1)

Because each value which is written to the AOUT-1 board involves more than eight bits of data, two data ports must be used each time an output channel is set to a new value.

As shown in the diagrams above, the low data port contains bits 0 thru 7 of the new value. The high data port contains the upper two data bits (bits 8-9) in bits 0 and 1 respectively. The other bits in the high data port are used for:

Channel Number - Bits 4 and 5 are used to specify the output channel to be updated. The possible selections are shown below.

B5	B4	Channel #
0	0	0
0	1	1
1	0	2
1	1	3

Output Disable - Bit 7 can be set high to disable the outputs of the AOUT-1 board. The outputs of the board will remain at approximately zero volts until this port is written to again with bit 7 set low. Disabling the outputs does not affect the contents of the on-board memory. Each channel will be restored to its previous level when the outputs are once again enabled.

In actual operation all 10 bits of data must be written to the output channel at the same time. The AOUT-1 board accomplishes this by "saving" the data written to the Low Byte Data Port, and actually transferring it to the appropriate output channel when data is being written to the the High Byte Data Port. This means that the Low Data Port must always be written to first and that no change in output voltage will occur until the High Data Port is written to.

A normal update of an output channel is as follows:

1) Write the lower 8 bits of data to the Low Data Port (the data is stored on-board, no other action occurs).

2) Write the upper two data bits and channel select bits to the High Data Port (all 10 bits of data are now transferred to the requested channel and the output voltage changes).

Initialization

When power is first applied to the AOUT-1 board, all of the output lines are disabled. This prevents random data values, which appear in the on-board memory at power-up time, from affecting external devices which are connected to the AOUT-1 card.

Before the board is used it should be initialized by writing zero (or some other desired starting value) to each of the four channels. These initial values should be written to the board with the Disable bit ON (high) to keep the outputs disabled until all four of the channels have been cleared. Once all of the channels have been cleared (or set to a starting value), the outputs should be enabled by writing data to the board with the Disable bit OFF (low).

Initialization examples are included in the Software Examples section below.

It should also be noted that the Disable bit can be used to disable the output lines at any time. In particular it can be used in emergency or panic stop routines to quickly bring all output channels to approximately zero volts.

Note: The AOUT-1 also disables the output lines when a system reset occurs if the RST jumper is in place. See the Jumper Options section for more information.

Software Examples

Operation of the AOUT-1 board is straightforward once a short subroutine has been written to format the 10 bit value into two separate bytes, add the desired channel number, and write the result to the board. The examples below illustrate both initialization and typical use of the board. These examples assume that the board has been addressed at hex port 30 (decimal 48).

C4 BASIC - The C4 BASIC language from VersaLogic includes the AOUT statement specifically for the AOUT-1 board. It is used as follows:

```
150 REM Initialize the board at power-up.
160 AOUT &30,CLEAR

200 REM Set channel 0 to 5.00 volts.
210 AOUT &30,0,500

220 REM a subroutine to set channel C to V volts.
210 AOUT &30,C,V : RETURN
```

Microsoft BASIC - The popular Microsoft BASIC language is available for a number of machines and is used below to demonstrate a typical AOUT-1 interface routine in BASIC.

```
100 REM initialize the AOUT-1 board at power-up
110 OUT(48,0) : FOR X=0 to 3 : OUT(49,128+X*16) : NEXT X : OUT(49,0)

150 REM set channel 2 to 4.15 volts
160 C=2 : V=415 : GOSUB 500
 .
 .
500 REM a subroutine to set any channel C to the voltage V.
510 X=INT(V/256) : OUT(48,V-X*256) : OUT(49,X+C*16)
520 RETURN
```

Assembly Language - The following example is written in 8085/Z80 code using 8085 mnemonics.

```
                    ;
                    ; *** AOUT-1 code example for 8085/Z80 type processors
                    ;
                    ;
 0030 =             AOUTL   EQU     30H      ;AOUT-1 board, low data port.
 0031 =             AOUTH   EQU     AOUTL+1  ;AOUT-1 board, high data port.
                    ;
 0200                       ORG     200H
                    ;
                    ; *** Initialize the AOUT-1 board at power-up *********
                    ;
 0200 3E00          INIT    MVI     A,0      ;Write zero to lower port latch.
 0202 D330                  OUT     AOUTL
 0204 010300                LXI     B,3      ;Loop for chan. 0-3
 0207 78            INIT1   MOV     A,B      ;Move channel # to A
 0208 07                    RLC              ;Rotate it into D4&D5
 0209 07                    RLC
 020A 07                    RLC
 020B 07                    RLC
 020C F680                  ORI     80H      ;Set output disable bit
 020E D331                  OUT     AOUTH    ;Write it
 0210 05                    DCR     B        ;Count down the chan. #
 0211 F20702                JP      INIT1    ;Repeat for four channels
                    ;
 0214 AF                    XRA     A        ;Clear A
 0215 D331                  OUT     AOUTH    ;Enable the AOUT-1 outputs
                    ;
                    ;********** end of initialization ******************
                    ;
                    ;
```

```
                    ;
                    ; ** Typical use of the AOUT-1
                    ; ** (uses the subroutine below)
                    ;
                    ; Set channel 2 to 4.12 volts
                    ;
0217 0602                   MVI     B,2         ;Set the channel #
0219 219C01                 LXI     H,412       ;Set the data value
021C CD1F02                 CALL    AOUT        ;Do it
                    ;
                    ;       (program continues with other tasks)
                    ;
                    ;
                    ;
                    ;*** AOUT-1 output subroutine **********************
                    ;*** Writes data (in H&L) to the specified channel (in B)
                    ;
021F 7D             AOUT    MOV     A,L         ;Move low data bits to A
0220 D330                   OUT     AOUTL       ;Write to low data port
0222 78                     MOV     A,B         ;Get channel #
0223 07                     RLC                 ;Rotate chan. # into D4&D5
0224 07                     RLC
0225 07                     RLC
0226 07                     RLC
0227 B4D331                 ORA     H           ;Combine with upper data bits
022A D331                   OUT     AOUTH       ;Write it
022C C9                     RET                 ;and return to caller
                    ;
                    ;**************** end of subroutine ****************
                    ;
022D                        END
```

CALIBRATION

The AOUT-1 board is supplied precalibrated at 10mv per count (10.23 volts full scale) and is ready to operate. It is a good practice, depending on the accuracy requirements of the application, to recalibrate the board every 12 months to compensate for any component aging that has occurred. The two on-board adjustments, ZERO and SPAN, are found near the 26 pin connector at the edge of the board.

The calibration procedure requires some way to write data to the board. This can be done with a monitor or debugger program, or with a short routine such as the C4 BASIC program shown below.

```
100 PRINT 'The AOUT-1 address switch must be set to "1" for this test'
110 AOUT 10,CLEAR : REM initialize the board
120 PRINT 'All outputs should now be at zero' : PRINT
120 INPUT 'Channel' C, 'Value (0-1023)' V
130 AOUT 10,C,V
140 GOTO 120
```

The calibration procedure is as follows:

1. Zero Adjustment
   A. Turn on the system and initialize the AOUT-1 board (write zeros to all the channels).
   B. Adjust the "ZERO" pot for the closest "0" reading on all channels.

2. Span Adjustment
   A. Write 1000 to one of the channels.
   B. Adjust the "SPAN" pot for an output voltage of 10.00 volts on the selected channel.

Note: The procedure above sets the board to the normal output span of 10.23 volts max. (with the maximum input value of 1023) or 10mv per count. A slightly different span (scale) can be accommodated by writing the maximum input value of 1023 (decimal) to the board in step 2A. The desired full scale output voltage can then be selected in step 2B. The voltage output change for each step in input value can be found by dividing the full scale voltage by 1023.

JUMPER OPTIONS

The jumper options for the AOUT-1 board are as follows.

Name - Description

A1, A2, A3 - Allows the board to be addressed to locations in addition to the ten provided by the "Address" rotary switch. The board will be selected when address lines A1-A3 are low (open) or high (jumpered). For special addressing requirements contact the factory for assistance.

IOX - Allows the board to be used in systems that include extended I/O addressing. The board may be located in either the normal (IOX open) or extended (IOX jumpered) I/O maps. Most systems will required this jumper to be open. The IOX jumper is located near the address switch.

RST - Causes the outputs of the board to be disabled whenever a system reset occurs (if the jumper is in place). The outputs remain disabled (near zero volts) until they are enabled by writing to the High Data Port with the disable bit low (see the Software Interface section for more information. As delivered this jumper is open. The RST jumper is located at the bottom right corner of the board, under U20.

AGND - This jumper allows the the AGND (analog ground) pins on the output connector to be disconnected from the analog ground line on the AOUT-1 board. Note: The analog ground signal eventually connects to the STD BUS system digital ground as well. As delivered these pads are jumpered with a printed circuit trace. The AGND pads are located near the output connector. Refer to the AOUT-1 Schematic for more information.

OUT0-OUT3 - Allows the signals from channels 0 thru 3 to be routed on several different output connector pins. See the Output Connection section or the AOUT-1 Schematic for more information.

SPECIFICATIONS

Output Channels: Four.

Resolution: 1023 steps (10 bits).

Output Range: 0-10.23 volts.

Input Format: 10 bit binary word.

System I/O Locations Required: Two.

Software Interface:
- Low Port: Eight data bits.
- High Port: Two data bits plus two channel select bits.

Output Current: 5ma/channel.

Slew Rate: .1V/us.

Settling Time: 50us + slew max.

Nonlinearity: ± 1/2 LSB max.

Total Error: ±.1% of FSR max.

Temperature Coefficient:
- Span: ±100ppm/·C of FSR max.
- Zero: ±25uv/·C max.

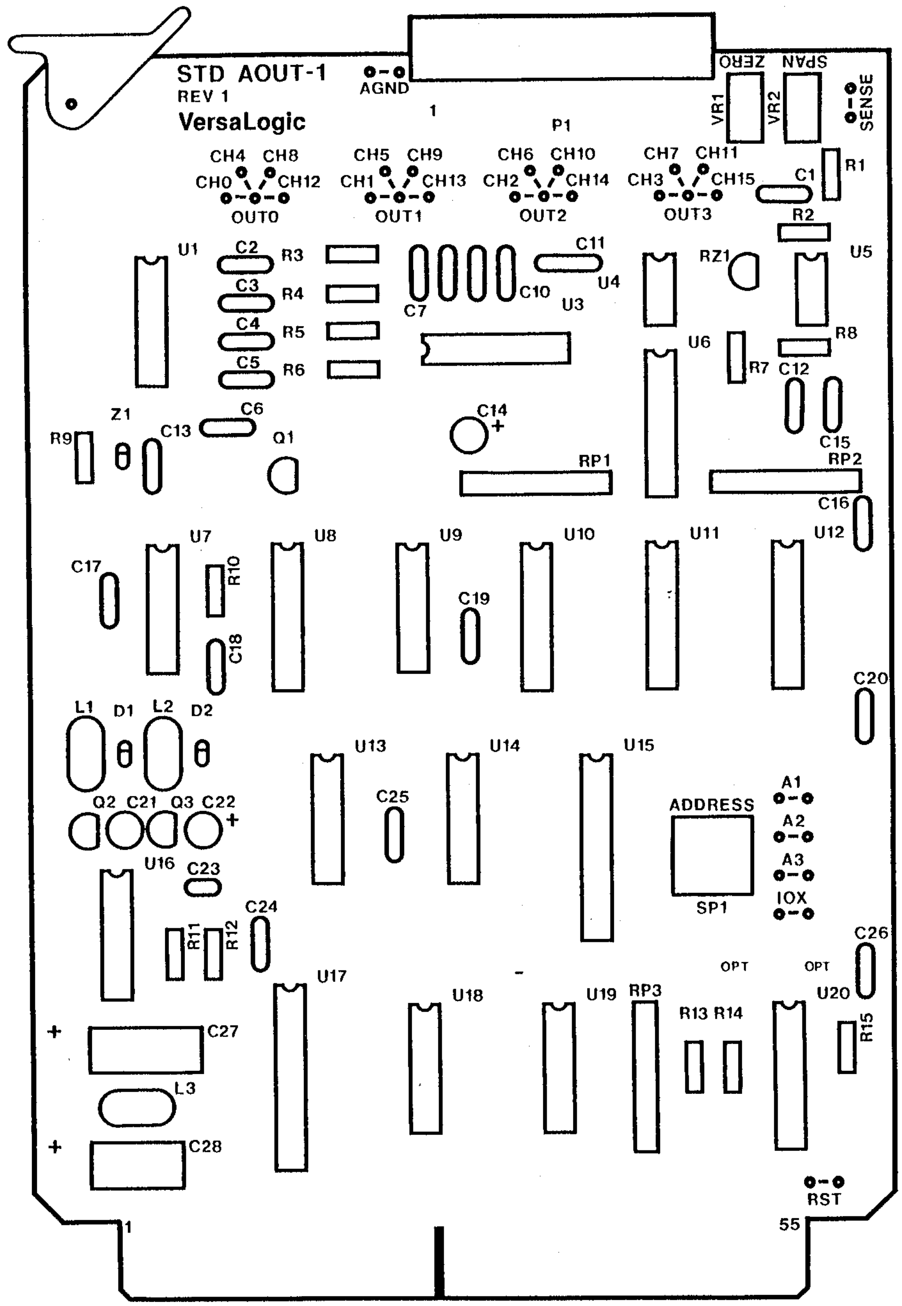
Size: 4.5" X 6.6" X .5".

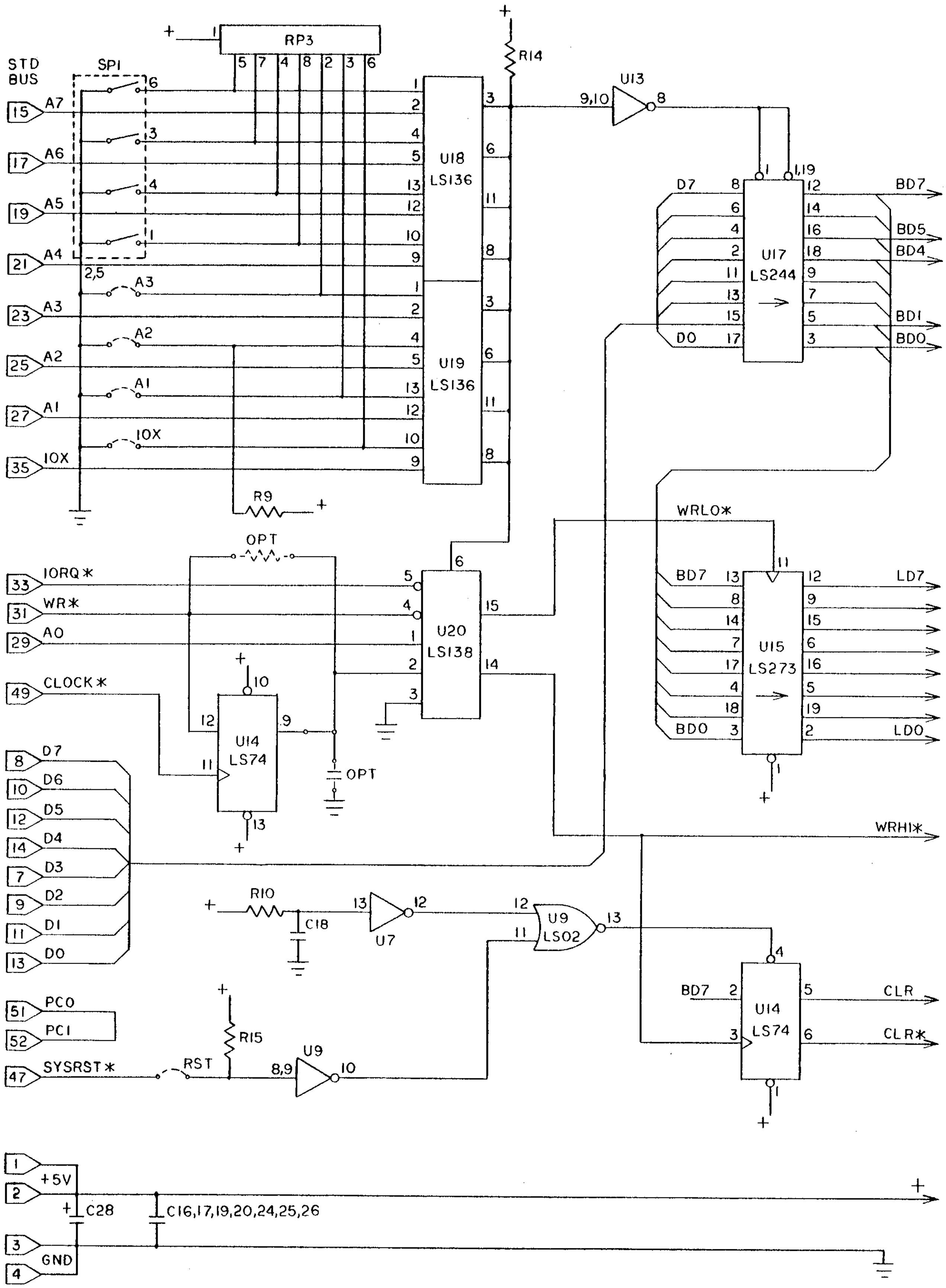
Operating Temperature: 0 to 50·C.

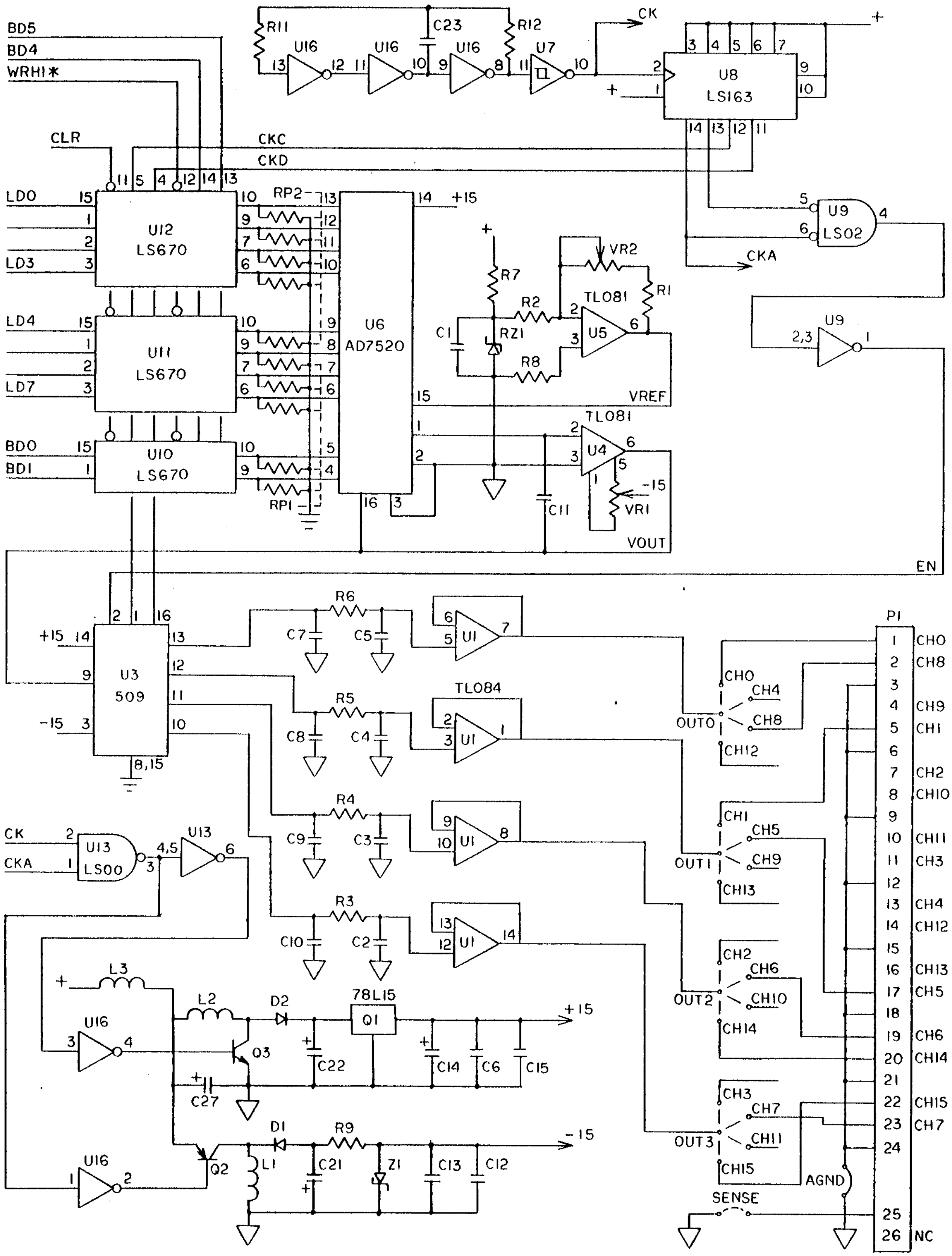
Power Requirements: +5V (±5%) at 500ma typical.

Connectors:
- STD BUS: 56 pin .125" card edge.
- Analog Output: 26 pin (dual 13) .1" header.

Construction: Epoxy glass PC board with solder mask and gold plated connector fingers.


STD AOUT-1
REV 1
VersaLogic
AGND
P1
ZERO
SPAN
VR1
VR2
SENSE
CH4 CH8
CH0 CH12
OUT0
CH5 CH9
CH1 CH13
OUT1
CH6 CH10
CH2 CH14
OUT2
CH7 CH11
CH3 CH15
OUT3
C1 R1 R2
U1 C2 R3 C3 R4 C4 R5 C5 R6
C7 C10 C11 U4 U3
RZ1 U5 U6 R7 R8 C12 C15
Z1 R9 C13 C6 Q1 C14 RP1 RP2 C16
U7 U8 U9 U10 U11 U12
C17 R10 C18 C19 C20
L1 D1 L2 D2
Q2 C21 Q3 C22
U13 U14 U15 C25
ADDRESS
SP1
A1 A2 A3 IOX
U16 C23 C24 R11 R12
C26
OPT OPT
U17 U18 U19 RP3 R13 R14 U20 R15
C27 L3 C28
RST
1 55


STD BUS
SP1
RP3
R14
U13
U18 LS136
U19 LS136
U17 LS244
U20 LS138
U15 LS273
U14 LS74
U9 LS02
U7
U9
R9
R10
C18
R15
RST
OPT
A7
A6
A5
A4
A3
A2
A1
IOX
IORQ*
WR*
A0
CLOCK*
D7
D6
D5
D4
D3
D2
D1
D0
PC0
PC1
SYSRST*
BD7
BD5
BD4
BD1
BD0
WRLO*
WRHI*
LD7
LD0
CLR
CLR*
+5V
GND
C28
C16,17,19,20,24,25,26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BD4
WRHI*
CLR
CKC
CKD
LD0
LD3
LD4
LD7
BD0
BD1
U12
LS670
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LS670
U10
LS670
RP2
RP1
U6
AD7520
+15
R11
R12
C23
U16
U7
CK
U8
LS163
U9
LS02
CKA
EN
R7
R2
R8
RZ1
C1
VR2
R1
TL081
U5
VREF
U4
VR1
-15
C11
VOUT
U3
509
+15
-15
R6
R5
R4
R3
C7
C5
C8
C4
C9
C3
C10
C2
U1
TL084
OUT0
OUT1
OUT2
OUT3
CH0
CH1
CH2
CH3
CH4
CH5
CH6
CH7
CH8
CH9
CH10
CH11
CH12
CH13
CH14
CH15
P1
AGND
SENSE
NC
U13
LS00
L3
L2
L1
D2
D1
78L15
Q1
Q2
Q3
C22
C27
C14
C6
C15
C21
C13
C12
R9
Z1

STD AOUT-1 PARTS LIST

9/1/89
Rev. 1.0

Capacitors

C1, C16, C17, C19, C20, C24, C25, C26	.01 uf Ceramic Disk, 50V
C2, C3, C4, C5	680 pf X7R, Ceramic
C7, C8, C9, C10	.0047 uf X7R, Ceramic
C11	22 pf Ceramic
C14, C21, C22	10 uf Tantalum, 16V
C6, C12, C13, C15, C18	.1 uf Ceramic
C23	270 pf NPO, Ceramic
C27	220 uf Electrolytic, 16V
C28	22 uf Electrolytic, 25V

Inductors

L1, L2	100 mH
L3	10 mH

Integrated Circuits

U1	TL084ACP
U3	DG509
U4, U5	TL081CP
U6	AD7520LN
U7	LS14
U8	LS163
U9	LS02
U10, U11, U12	LS670
U13	LS00
U14	LS74

U15	LS273
U16	74HC04
U17	LS244
U18, U19	LS136
U20	LS138

Resistors

R1	69K8 ohm, 1%, Metal
R2, R8	18K2 ohm, 1%, Metal
R3, R4, R5, R6	33K ohm, 5%, 1/4W
R7	2K2 ohm, 5%, 1/4W
R9	200 ohm, 5%, 1/4W
R10, R13, R15	10K ohm, 5%, 1/4W
R11, R14	1K ohm, 5%, 1/4W
R12	4K7 ohm, 5%, 1/4W

Resistor Pack

RP1, RP2	4K7 ohm, 7 Res., SIP
RP3	10K ohm, 7 Res., SIP

Semiconductors

D1, D2	IN4148 Diode
Q1	78L15 Regulator
Q2	PN2907 Transistor
Q3	PN2222 Transistor
RZ1	LM336Z Reference
Z1	IN5245 Zener

Switch Pack

SPI	BCD Rotary

Variable Resistors

VR1	100K, 15 Turn
VR2	10K, 15 Turn

Hardware

P1	26 pin .1" right angle header
Card Ejector	CP-06
Shipping Bag	Anti-static