Micro Technology Unlimited

K-1002 8 BIT AUDIO DIGITAL TO ANALOG CONVERTER

HARDWARE MANUAL

JULY 1979

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K-1002 UNPACKING AND INSTALLATION

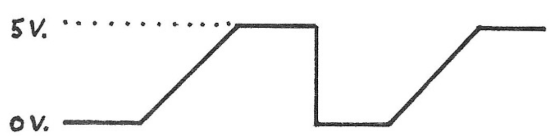
The K-1002 8 Bit Audio System for the KIM/SYM/AIM is a carefully engineered, manufactured, and tested product that should operate perfectly when handled and installed according to the following instructions. Since CMOS integrated circuits are used on the board, damage from static discharge is possible. When handling the board, always pick it up by the output jack which is connected to ground. Before plugging it into or removing it from the computer, discharge yourself to ground (the bottom plate of a K-1000 series power supply is ideal).

Installation is accomplished by obtaining a double sided 44 pin (22 pins each side) edge connector similar to that used on the application connector of the computer. Following the pinouts given on the next page, make a cable to run from this connector to the application connector on the computer. Users of the K-1005 card file may obtain an application motherboard which reduces the wiring job to about a dozen wire-wrap connections. Any 4, 8, or 16 ohm speaker may be plugged into the RCA phono jack at the rear of the board. Alternatively an audio cable may be plugged in and an external amplifier used for more volume such as at a club meeting or show.

A unique feature of the K-1002 is an auxiliary input to the audio power amplifier. This input can be connected to the cassette audio output pin to provide a monitor while recording. On a KIM-1, it will monitor both recording and playback. If not used, the auxiliary input pin may simply be left open.

To verify that the board is working, enter one of the programs below and start execution at zero. A clear robust buzz should be heard in the speaker and the volume control should have a range from complete silence to somewhat above the point of distortion. If the sound is weak or has a particularly prominent harmonic, check the wiring for missing or scrambled bits. If an oscilloscope is available, the waveform should resemble that pictured below. If the ramp portion of the waveform is wrong, verify that each bit is reaching the D-to-A converter IC's.

KIM-1		SYM-1		AIM-65	
0000	A9 FF 8D 01	0000	A9 FF 8D 03	0000	A9 FF 8D 03
0004	17 8D 00 17	0004	A0 8D 0F A0	0004	A0 8D 0F A0
0008	A2 02 20 1A	0008	A2 02 20 1A	0008	A2 02 20 1A
000C	00 CE 00 17	000C	00 CE 0F A0	000C	00 CE 0F A0
0010	D0 FB A2 02	0010	D0 FB A2 02	0010	D0 FB A2 02
0014	20 1A 00 4C	0014	20 1A 00 4C	0014	20 1A 00 4C
0018	00 00 A0 C8	0018	00 00 A0 C8	0018	00 00 A0 C8
001C	88 D0 FD CA	001C	88 D0 FD CA	001C	88 D0 FD CA
0020	D0 F8 60	0020	D0 F8 60	0020	D0 F8 60



This completes checkout of the 8 Bit Audio System. If any problems are experienced, see the section on troubleshooting before returning the board to the factory.

SPECIFICATIONS

Physical Size: 4 3/4 inches wide by 3 inches deep overall by 1.13 inches thick

Connections: 1 set of 44 edge fingers, 22 on each side, .156" spacing

DAC section: 8 bits, offset binary encoded, typical 1/4 LSB linearity, guarenteed monotonic, 5 volt swing, 6.25K output impedance, 5 volt supply is filtered and used as the reference voltage.

Filter section: 6 poles, 0.5dB Chebyshev response, cutoff frequency is 3.5kHz.

Power amp section: power output: 150MW into 16 ohms, 300MW into 8 ohms, 500MW into 4 ohms. Amplifier response is flat within 3dB from 30 to 20kHz with an 8 ohm load. Distortion at full power output into 8 ohms at 1kHz is less than 2%.

Power requirements: Single +5 volt supply. Ripple and noise within the audio range should be less than 20MV.

Power Consumption: Quiescent current drain is less than 50MA. Worst case drain at full power, 4 ohm load, and square wave output is 300MA.

Signal loading: Less than 10uA and 10pF loading on the 8 binary inputs. Auxiliary input feeds 240K ohms to ground.

PIN CONNECTIONS
(industry standard numbering)

Computer Application Connector	K-1002 Connector	Signal Name
A-1	1	GROUND
A-14	2	BIT 0 (LSB)
A-4	3	BIT 1
A-3	4	BIT 2
A-2	5	BIT 3
A-5	6	BIT 4
A-6	7	BIT 5
A-7	8	BIT 6
A-8	9	BIT 7 (MSB)
A-P*	10	AUXILIARY INPUT
A-A	11	+5 VOLTS
	12-22	NO CONNECTION
A-A	A	+5 VOLTS
	B-Z	NO CONNECTION

* Used for cassette tape monitoring, not required for operation.

PRINCIPLES OF OPERATION

The K-1002 8 Bit Audio System consists of three distinct sections. The 8 bit digital-to-analog converter (DAC) accepts an 8 bit binary input from an output port on the computer and produces a DC voltage directly proportional to the unsigned binary value of the input. The 6-pole lowpass filter blocks all sampling distortion frequencies above approximately 3.5kHz. This filter is necessary for clean sounding music from the DAC. The audio power amplifier boosts the filter output signal to the level required for driving a speaker. A volume control determines the gain of the amplifier and thus the volume of the sound reproduced in the speaker. In order for the board to operate solely from a single 5 volt power supply, several innovative circuit techniques have been incorporated.

Looking at the DAC section first (left portion of the schematic drawing), it is seen that the weighted resistor method of conversion is used. The CMOS buffers in U1 and U2 make very good analog switches which switch their outputs between exactly ground and exactly the supply voltage (+5 volts) in response to the input signal. The only error in this switching action is a finite output impedance of approximately 200 ohms. CMOS buffers, rather than inverters, are used because the two stages of "gain" internally assures complete switching of the output even if the input swings less than 5 volts. The DAC network produces an output voltage directly with a source impedance of approximately 6.25K. With all zeroes input, the output is zero volts; with all ones input, the output is 5 volts. Loading the output has no effect on linearity but it will reduce the signal swing.

In order to insure accurate, monotonic performance of the DAC, the most significant bit is actually four CMOS gates and four 51K resistors in parallel while the next most significant bit is two in parallel. The remaining bits are single gates since the ratio of the weighting resistors to the gate output impedance is large enough to ignore. By using parallel and series combinations of 51K resistors for the most significant 5 bits, it is possible to use relatively inaccurate resistors in the DAC and still achieve 1/4 LSB linearity which is about .2%. This is due to statistical averaging among the resistors, particularly the critical most significant bit. Even so, factory assembled units have had the 51K resistors matched to within 1%. Although the more common R-2R resistor ladder network could have been used, more resistors would have been required to get the same degree of statistical matching. An integrated circuit DAC was not practical since all that are currently available require a negative supply voltage for either the DAC itself or for a current-to-voltage converter operational amplifier. Note that the 5 volt power supply is filtered and used as a reference for the DAC. While small amounts of noise are filtered out, 60Hz ripple on the 5 volt supply is likely to result in hum from the speaker.

The filter circuit is where things start getting unconventional. The filter actually consists of three two-pole stages connected in cascade. Each section is a resonant lowpass filter, i.e., the response curve may peak somewhat just before cutoff. With proper selection of section cutoff frequencies and Q factors (peaking), a very nearly flat passband and sharp cutoff is obtained. Passband ripple is less than .5dB and the cutoff slope is such that 30dB attenuation is obtained at just 1.35 times the cutoff frequency of 3.5kHz. Note that the 5 volt swing of the DAC is reduced to about 2.5 volts through the filter by virtue of the 220K input resistor to the first filter stage.

Each filter section is implemented as a biquadratic filter which consists of an inverting summing amplifier, a leaky integrator, and an ideal integrator all connected in a loop. Although three operational amplifiers are required for the circuit, its advantages are many. In particular, high Q factors are possible with modest amplifier gain. In addition, sensitivity of the response curve to component tolerance is very low. These characteristics allow the use of linearly biased CMOS gates as inverting operational amplifiers. Performance of the filter using the CMOS gates is indistinguishable from the performance using true op-amps such as a 741. See the National Semiconductor CMOS data book for more information on linear CMOS applications.

The audio power amplifier is a special high efficiency design that allows a significant power output with only a single 5 volt power supply and no output transformer. Three parallel connected CMOS gates provide most of the voltage amplification in the circuit as well as presenting a high input impedance and having a moderately low output impedance. The output stage is fully complementary and incorporates considerable local feedback of its own. The voltage gain of the output stage is approximately 18. Overall feedback from the output back to the voltage amplifier input completes the loop and gives a closed loop gain of about 3.5 with maximum volume. The 92PU01 (NPN) and 92PU51 (PNP) output transistors actually contain one-amp capability transistor chips in a modified TO-92 plastic case. This is the same chip as used in the Motorola MPSU01 and MPSU51 plastic power transistors. With an 8 ohm load, the amplifier output can swing to within .3 volts of the 5 volt supply or ground before saturating. The 2.7 ohm resistor and .1uF capacitor (R46 and C9) accross the output prevent possible oscillation with inductive loads. R39, R40, D1, and D2 form a bias network which allows a couple of milliamps to flow in the output transistors at all times to minimize class-B crossover distortion.

TROUBLESHOOTING

Diagnosing problems with the K-1002 board is fairly simple because of the unidirectional signal flow and minimal interaction among circuit components. If the board is completely inoperative, first do a thorough visual inspection of the board. Look on the solder side of the board for component leads that may be bent and shorting out to adjacent pads or PC runs. Check for loose components and the possibility of a cold solder joint.

If careful inspection fails to turn up anything, enter and run the program given earlier. Then using a scope or amplifier/speaker if a scope is unavailable, find out where the signal is being lost. The first point to check is the node where all of the DAC resistors are tied together. The signal should be as shown on page one with ground and +5 voltage levels. Next check the output of the first filter section which is U3-8. The waveform should be somewhat rounded with voltage levels of about 1.25 and 3.75 volts. The next stage output (U3-6) should be somewhat less rounded with a hint of ringing on the square edges of the wave. Again the signal levels (less ringing) should be 1.25 snd 3.75 volts. The last stage output (U4-6) has considerable ringing at a little over 3kHz but still the same voltage levels. If the signal is lost anywhere in the filter or the voltage levels are considerably offset (greater than .5 volt deviation) from their proper values first wiggle all associated components to see if anything changes. If this fails, the associated CD4069 (the 74C04 is an equivalent) should be replaced. Be sure to use a CD4069 or a 74C04; other varieties of inverters may not be suitable for linear operation or may have too high an internal impedance.

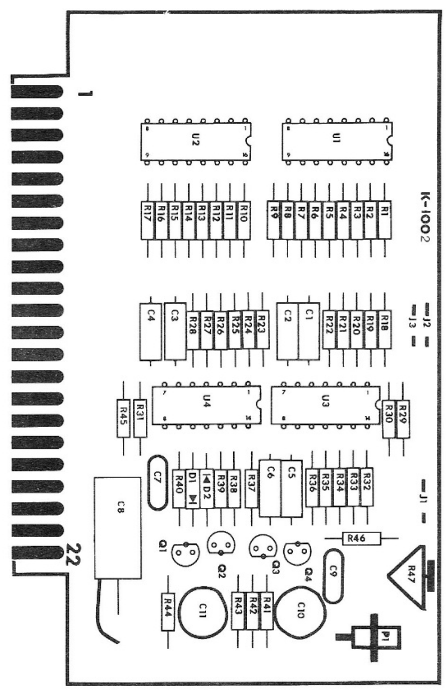
If the problem is in the power amplifier, first measure the output transistor collector voltage (the little tabs sticking out the top of the transistors are the collectors) with no signal. This voltage should be within a quarter volt of 2.5 volts. If it is off considerably, one of the 4 transistors in the output stage may be shorted or open or the CMOS voltage amplifier may be bad. Temporarily cut the line running from U4-8, 10, and 12 to the junction of D1 and D2 and measure the collector voltage again. If it is now centered, the CMOS is bad; otherwise one or more transistors are bad or one of the biasing resistors (R38-R43) is open. The amplifier is only partially protected from outout shorts so exercise care in connecting the speaker and don't run the unit with the volume full up when there is an obvious problem such as a speaker line short.

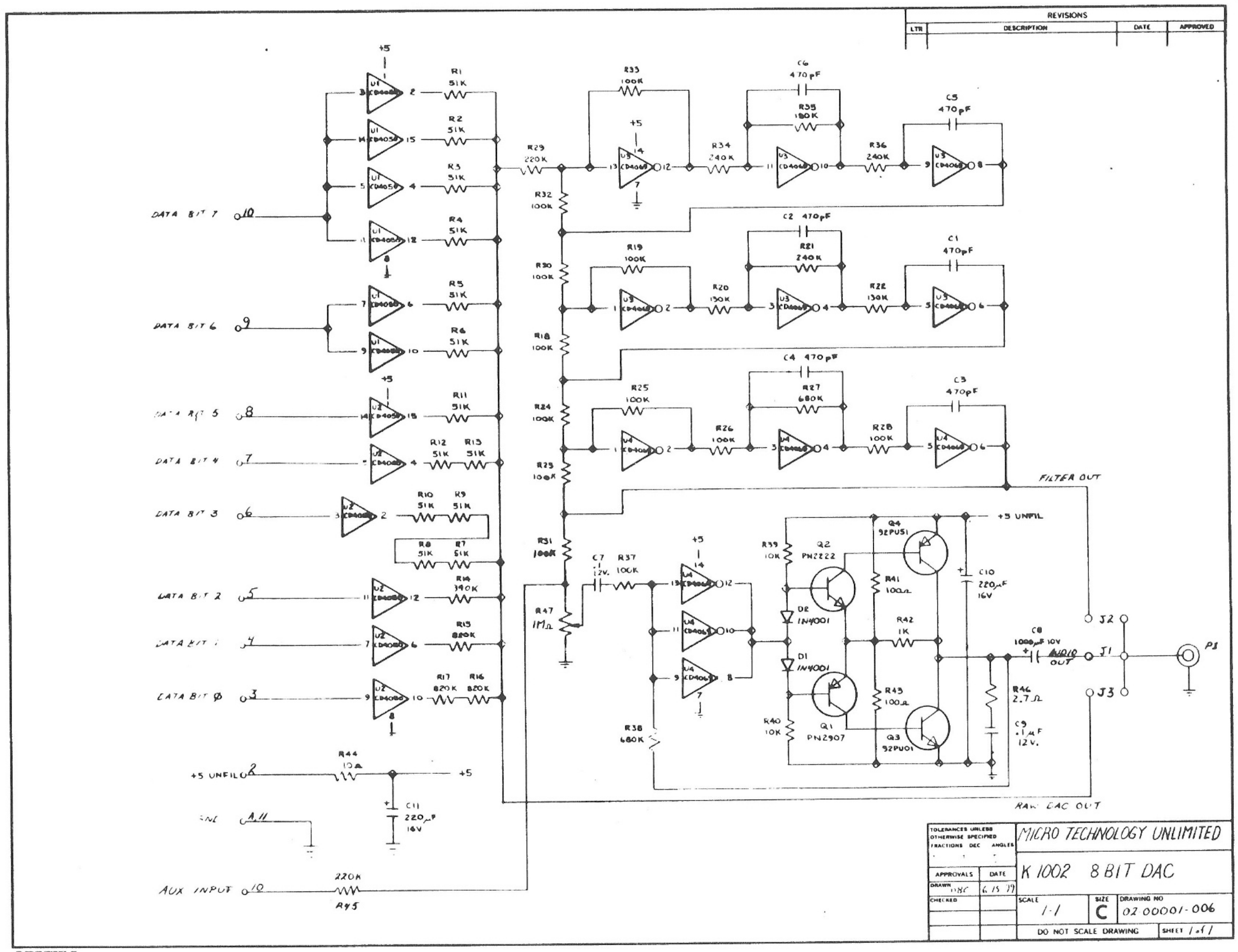
If there is hum in the speaker the problem is probably excessive noise in the +5 volt power. One possible cause is excessive impedance in the ground lead to the power supply. Try a heavier (#14 or #16) wire or a shorter wire to the power supply. Try also a heavier +5 wire to the computer if it is the source of the noise. If the power supply is just plain noisy, R44 and/or C11 can be increased to 27 ohms and 1000uF to improve 5 volt noise filtering.

If the customer is unable to find the problem, return the unit to the factory for servicing along with a description of the malfunction. This is a relatively simple board and factory repair can usually be accomplished in a couple of days.

K-1002 PARTS LIST

QUAN.	PART	DESIGNATION
1	2.7 OHM	R46
1	10 OHM	R44
2	100 OHM	R41,43
1	1K	R42
2	10K	R39,40
13	51K (MATCHED TO 1%)	R1-13
1	390K	R14
4	820K	R15-17,38
1	220K	R29
4	240K	R21,34,36,45
12	100K	R18,19,23-26,28,30-33,37
1	180K	R35
2	130K	R20,22
1	680K	R27
1	1M POT	R47
2	220UFD 6V ELECT	C10,11
6	470PF POLY CAP	C1-6
2	.1UFD 12V Z5U	C7,9
1	1000UF 10V ELECT	C8
2	1N4148 DIODES	D1,2
1	PN2222	Q2
1	PN2907	Q1
1	92PU01	Q3
1	92PU51	Q4
2	CD4050	U1,2
2	CD4069	U3,4
1	PHONO PLUG	
1	PC BOARD	


K-1002
1
22
U1
U2
U3
U4
R1 R2 R3 R4 R5 R6 R7 R8 R9
R10 R11 R12 R13 R14 R15 R16 R17
R18 R19 R20 R21 R22
R23 R24 R25 R26 R27 R28
C1 C2 C3 C4
J2
J3
R29 R30 R31 R45
C7 R40 D1 D2 R39 R38 R37 C6 C5 R36 R35 R34 R33 R32
J1
C8
R46
Q1 Q2 Q3 Q4
C9
R47
R44 C11 R43 R42 R41 C10
P1


MICRO TECHNOLOGY UNLIMITED
K 1002 8 BIT DAC
SCALE 1:1
SIZE C
DRAWING NO 02 00001-006
DO NOT SCALE DRAWING
SHEET 1 of 1
REVISIONS
LTR
DESCRIPTION
DATE
APPROVED
TOLERANCES UNLESS OTHERWISE SPECIFIED
FRACTIONS
DEC
ANGLES
APPROVALS
DATE
DRAWN
CHECKED
DATA BIT 7
DATA BIT 6
DATA BIT 5
DATA BIT 4
DATA BIT 3
DATA BIT 2
DATA BIT 1
DATA BIT Ø
+5 UNFIL
GND
AUX INPUT
FILTER OUT
RAW DAC OUT
+5 UNFIL
AUDIO OUT
J1
J2
J3
P1
CD4050
CD4069
PN2222
PN2907
92PU51
92PU01
1N4001