



**Micro  
Technology  
Unlimited**

**K-1002-2 8 BIT AUDIO  
DIGITAL TO ANALOG CONVERTER**

**FOR COMMODORE PET-2001  
HARDWARE MANUAL**

JULY 1979

COPYRIGHT NOTICE 1979

This manual is copyrighted. This includes the verbal description, PC artwork, diagnostic programs, operational programs, and specification sheets. The customer may make machine readable copies of the software routines for use only on computers owned directly by him or his company. They may not be reproduced for use with systems sold or rented.

Micro Technology Unlimited  
841 Galaxy Way  
PO Box 4596  
Manchester, NH 03108

## K-1002-2 UNPACKING AND INSTALLATION

The K-1002-2 8 Bit Audio System for the PET 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 PET, discharge yourself to the PET case first.

Installation is quite simple, merely plug the unit onto the user port and second cassette port of the PET. If other accessories or a second cassette unit are to be used, plug these onto the edge fingers of the K-1002-2. Our unit does not load any of the user port signals significantly because of the CMOS logic utilized. 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.

If the K-1002-2 Music Software package has been purchased, follow the instructions included with the cassette to verify that the board is working. Otherwise enter the following BASIC program and RUN it:

```
10 A=0: B=255: C=59459
20 POKE C,A: POKE C,B: GOTO 20
```

The resulting sound should resemble that of a misfiring race car. The volume control on the board should have a range from complete silence to slightly above the point of distortion.

Note that the CB2 signal from the 6522 VIA is also connected into the audio amplifier circuitry. Therefore any game programs or simple music programs that use this signal to generate sound will still be usable with the K-1002-2. One of these programs could also be used to check out the board.

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: 5 inches wide by 4 inches deep overall by 1.13 inches thick

Connections: 1 24 pin edge connector, 1 12 pin edge connector, 1 set of 24 edge fingers, and one set of 12 edge fingers. All signals are fed through from the edge connectors to the corresponding edge fingers.

DAC section: 8 bits, offset binary encoded, typical 1/4 LSB linearity, guaranteed 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. CB2 input is loaded by 240K to ground.

### PIN CONNECTIONS (industry standard numbering)

SIGNAL CONNECTOR	SIGNAL	SIGNAL CONNECTOR	SIGNAL
1	F.T.	A	F.T.
2	F.T.	B	F.T.
3	F.T.	C	DATA BIT 0
4	F.T.	D	DATA BIT 1
5	F.T.	E	DATA BIT 2
6	F.T.	F	DATA BIT 3
7	F.T.	H	DATA BIT 4
8	F.T.	J	DATA BIT 5
9	F.T.	K	DATA BIT 6
10	F.T.	L	DATA BIT 7
11	GROUND	M	CB2
12	GROUND	N	F.T.

  

POWER CONNECTOR	SIGNAL	POWER CONNECTOR	SIGNAL
1	N.C.	A	GROUND
2	N.C.	B	+5 VOLTS
3	N.C.	C	F.T.
4	N.C.	D	F.T.
5	N.C.	E	F.T.
6	N.C.	F	F.T.

**2**

\*\*\* F.T. = Feed Through to corresponding edge fingers, no on-board connection  
 \*\*\* N.C. = No connection to edge fingers or anything else

## PRINCIPLES OF OPERATION

The K-1002-2 8 Bit Audio System consists of three distinct sections. The 8 bit digital-to-analog converter (DAC) accepts an 8 bit binary input from the user port on the PET 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. The CB2 pin on the PET user port is also tied into the amplifier circuitry. 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 the 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 a one-amp capability transistor chip 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) across 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. R45 mixes the CB2 signal from the connector in with the filtered DAC output to allow continued use of this signal with existing game and simple music programs.

#### TROUBLESHOOTING

Diagnosing problems with the K-1002-2 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 a square wave modulated at a 60Hz rate (caused by timer interrupts in the PET) 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 wave edges. Again the signal levels (less ringing) should be 1.25 and 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 74004 is an equivalent) should be replaced. Be sure to use a CD4069 or a 74004; 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 output 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 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-1002-2 PET PARTS LIST

QUAN.	PART	DESIGNATION
1	2.7 OHM	R46
1	10 OHM	R44
2	100 OHM	R41, R43
1	1K	R42
2	10K	R39, R40
13	51K (MATCHED TO 1%)	R1 - R13
1	390K	R14
3	820K	R15 - R17
1	220K	R29
4	240K	R21, R34, R36, R45
12	100K	R18, R19, R23 - R26, R28, R30 - R33, R37
1	180K	R35
2	130K	R20, R22
1	680K	R27
1	1M POT	R47
2	220UF 6V ELECT	C10, C11
6	470PF POLY CAP	C1 - C6
2	.1UF 12V Z5U	C7, C9
1	1000UF 10V ELECT	C8
2	1N4148 DIODES	D1, D2
1	PN2222	Q2
1	PN2907	Q1
1	92PU01	Q3
1	92PU51	Q4
2	CD4050	U1, U2
2	CD4069	U3, U4
1	PHONO PLUG	
1	PC BOARD	
1	CONN PC SINGLE 6 .156SP	
1	CONN PC DUAL 12 .156SP	





