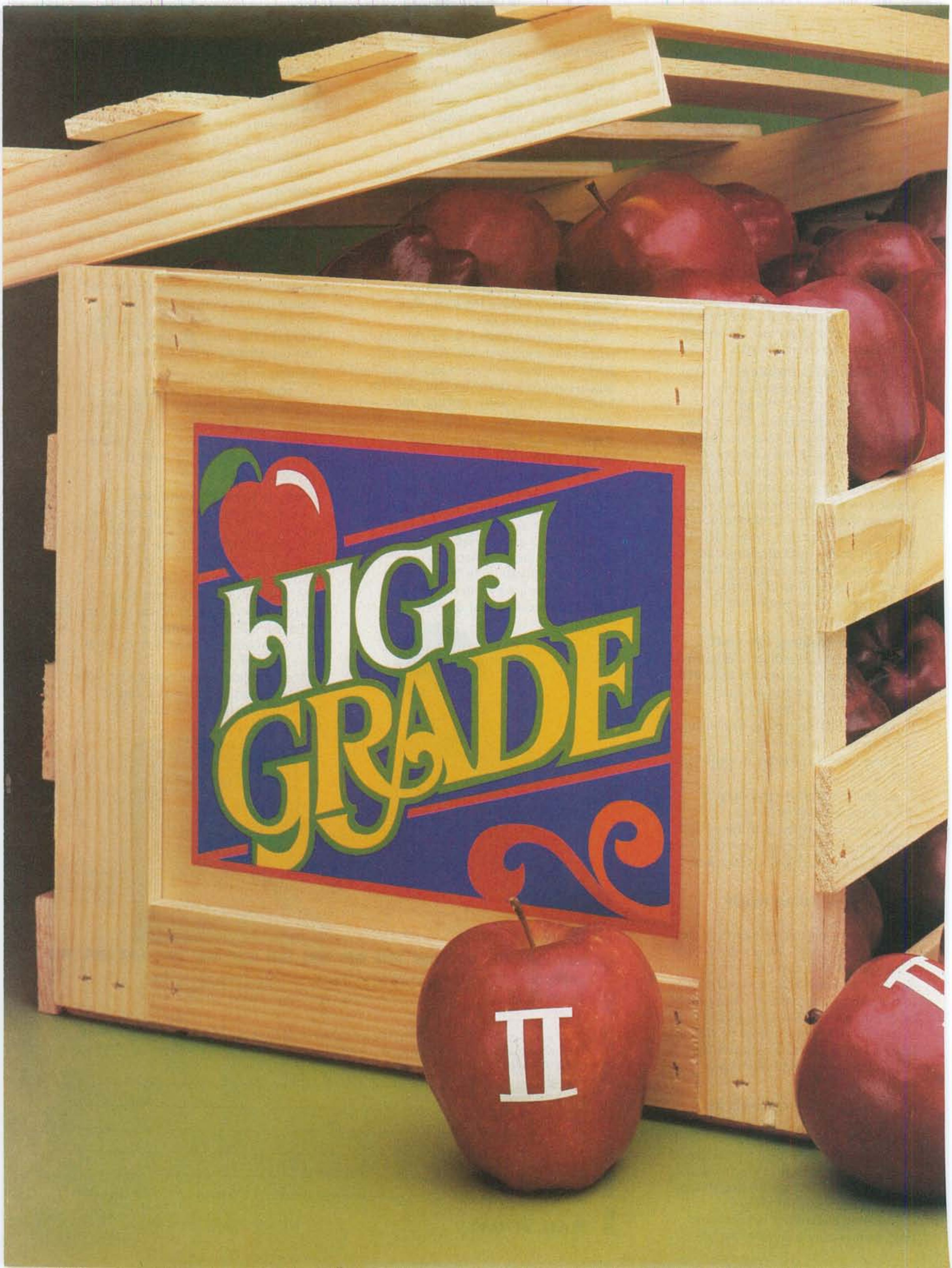
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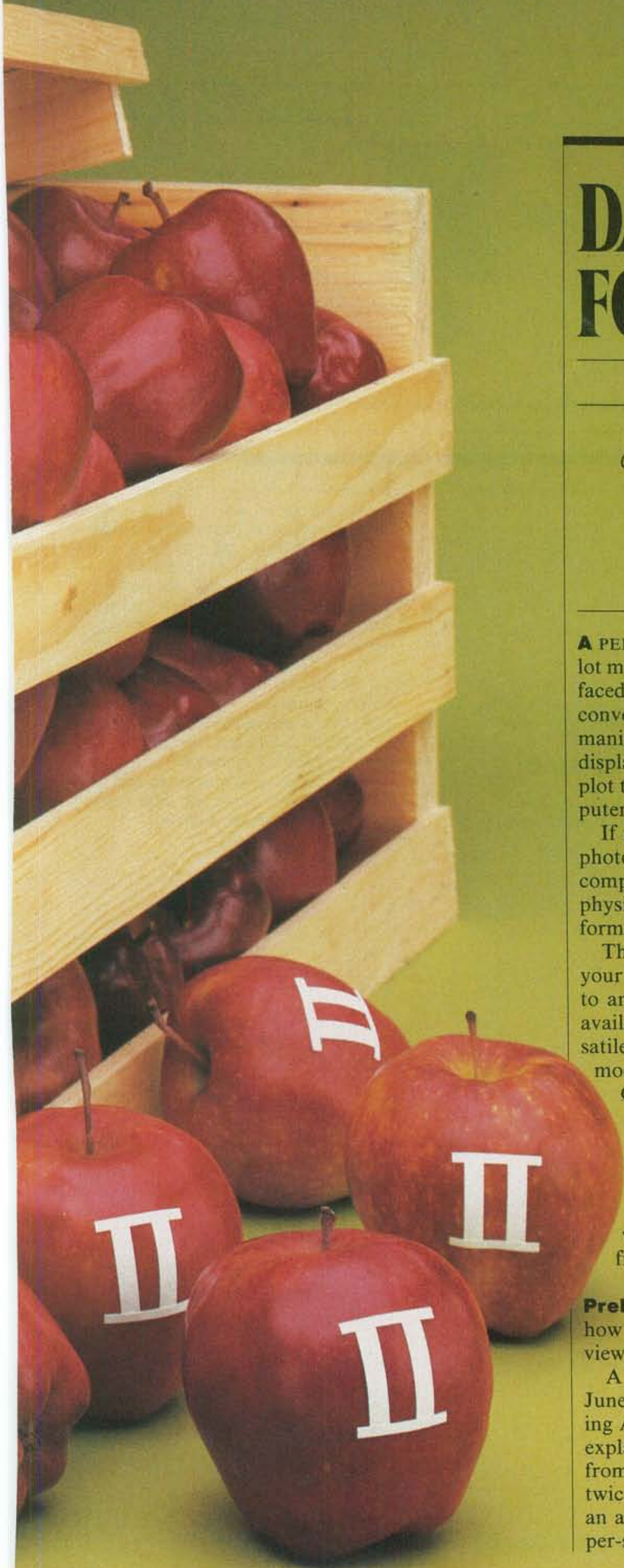


High-Grade

DATA CONVERTER FOR THE APPLE II

By Robert C. Nicklin

Part I: Analog/digital and digital/analog conversion increase the usefulness of your computer by allowing it to accept, manipulate, and display all kinds of physical data

A PERSONAL computer like the Apple II can be used to do a lot more than play games and calculate payrolls. When interfaced to analog-to-digital (A/D) and digital-to-analog (D/A) converters, your computer can capture waveforms, perform manipulations and mathematical operations on them, and display the new or changed waveforms on an oscilloscope or plot them on a chart recorder. Used in this manner, the computer becomes a "smart" storage scope.

If instead of a waveform you substitute the signal from a phototransistor, strain gauge, pressure transducer, etc., your computer can be made to sense and store information about physical variables. It can then display this information in a form and at a rate that's convenient for you.

The Data Converter presented here makes it possible for your computer to perform these functions. It can be adapted to any computer that has eight data and one control lines available at an I/O port. An additional circuit board, the Versatile Interface Adapter (VIA), was designed to interface the module to the Apple II computer. Together, the VIA and Converter equip the Apple computer to capture up to 17,000 data points per second from an ac or dc analog signal; amplify the incoming signal by up to 500 times; and output analog signals at rates up to 33,000 data points per second. In addition, an audio amplifier and speaker and two bidirectional digital I/O ports are provided. All operations of the Data Converter can be called from BASIC.

Preliminary Discussion. Before we get into the specifics of how the Data Converter accomplishes its task, let's briefly review how analog-to-digital conversion is performed.

A general discussion of A/D conversion appeared in the June 1982 issue of this magazine under the title of "Processing Analog Signals for Digital Systems." Briefly, this article explained how a waveform can be faithfully reconstructed from a series of samples when the sampling rate is at least twice the highest frequency present in the waveform. Hence, an analog/digital converter that samples at a 17,000 times-per-second rate can be used for signals whose highest

...*DATA CONVERTER*

frequency components don't exceed about 8.5 kHz.

Signal resolution is determined by the number of bits used by the A/D converter. An 8-bit converter, such as that used in the Data Converter presented here, can resolve a voltage range into 256 discrete intervals or 0.4% parts. A 9-volt reference, for example, sets a 0-to-9-volt range, with a resolution of 35 mV (9/256). If the signal is amplified 500 times, each interval represents 0.07 mV (35/500).

The same considerations apply to the

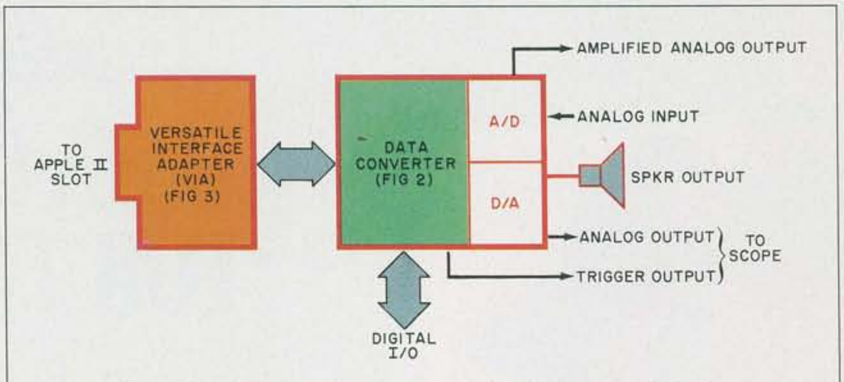


Fig. 1. Block diagram showing connections between major units.

PARTS LIST

B1—9-V transistor battery
B2—4.5-V battery (3 AA cells in series)
C1—100-pF, 25-V disc capacitor
C2—220-µF, 6-V electrolytic
C3,C5—0.1-µF, 25-V disc capacitor
C4—330-pF disc capacitor
D1—1N914 diode
IC1—TL092 dual op amp
IC2—AD7574 A/D converter
IC3—AD558 D/A converter
IC4—7416 open-collector hex inverter
IC5—LM386 audio amplifier
IC6—6522 PIA
IC7—Quad AND-gate
J1,J2,J5,J6,J7,J8—Phono jack
J3,J4—Banana jack (one red, one black)
All resistors are ¼-watt, 10% tolerance:
R1,R4,R8—10 kilohms
R2—1 megohm
R5,R6—1 kilohm
R7—5 kilohms
R9—50 kilohms
R10—100 kilohms
R11—500 kilohms
R12—200 kilohms
R13—2.2 kilohms
R15—1.5 kilohms
R3—10-kilohm trimmer potentiometer
R14—10-kilohm, audio-taper potentiometer
S1—Sp6t nonshorting rotary switch
S2—Spdt switch
S3—Dpdt switch
SPKR—Small 8-ohm loudspeaker
SO1,SO3,SO4—16-pin DIP socket
SO2—14-pin DIP socket
Misc.—Printed-circuit boards (2) or materials for fabricating same; 24" length of 16-conductor ribbon cable with 16-pin DIP header at each end; suitable-size enclosure; battery holders; control knobs (2); hookup wire; solder; machine hardware; quick-set epoxy cement; etc.

Note: The following are available from Nalan Computer Specialties, Box 1426, 106 Highland Park Lane, Boone, NC 28607: VIA board, including one cable, for $49.00; complete Data Converter kit, including machined and labeled chassis, batteries, and software on diskette, for $149.00.

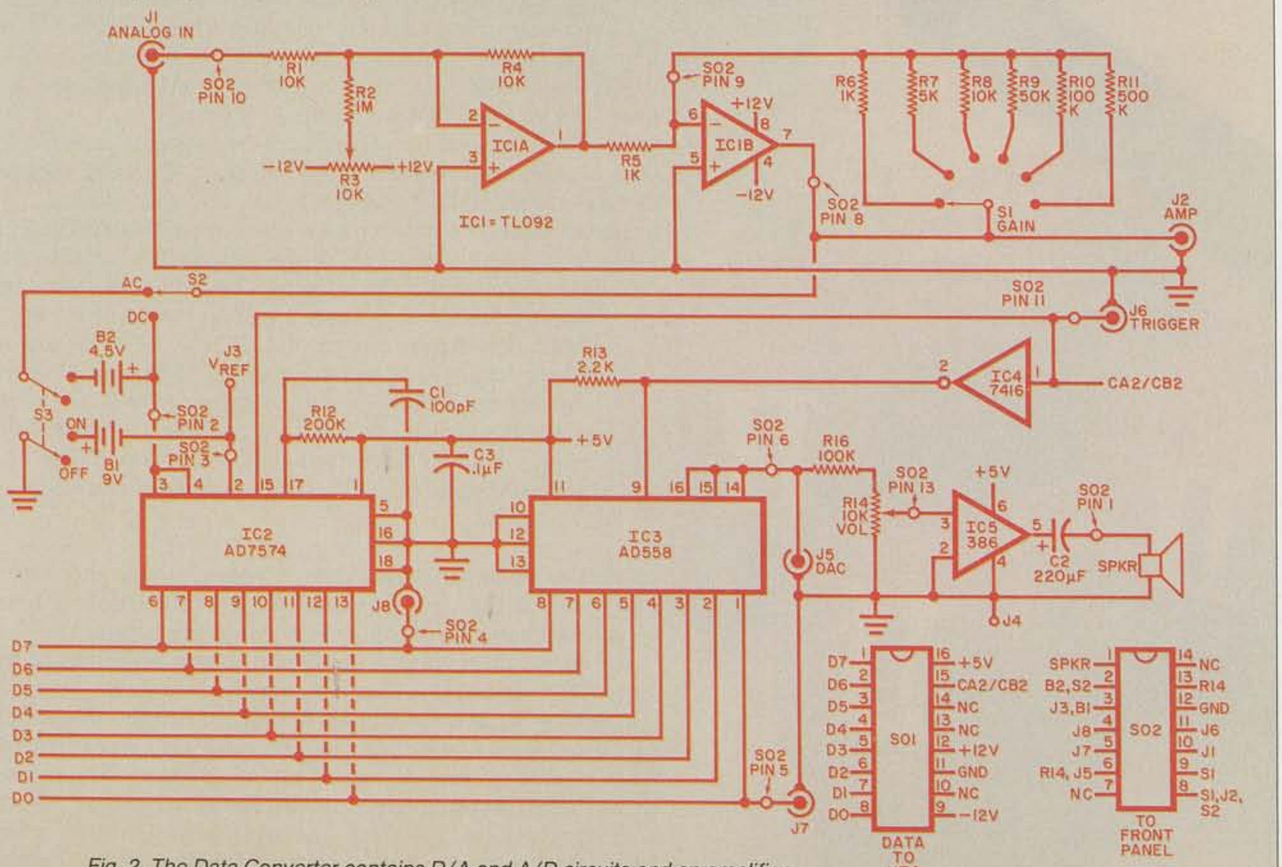


Fig. 2. The Data Converter contains D/A and A/D circuits and an amplifier.

D/A converter. The 8-bit device used in the Data Converter features 256 steps and, with its internal voltage reference, has a range from 0 to 2.56 volts. Consequently, each step represents 0.01 V (10 mV). With an output rate of 33,000 samples per second, the D/A converter could produce waveforms with frequency components to about 16,500 Hz.

Circuit Description. The Data Converter (Fig. 1) employs the Versatile Interface Adapter (VIA) designed to plug into any Apple II expansion slot. The converter interconnects with the VIA through a 16-conductor ribbon cable terminated at both ends with a DIP plug to provide eight bidirectional data, one control, and +12-, −12-, and +5-volt lines. The VIA contains two 8-bit bidirectional ports, each with two control lines. Only one port is used in this project, leaving the other available for a second converter or other I/O device.

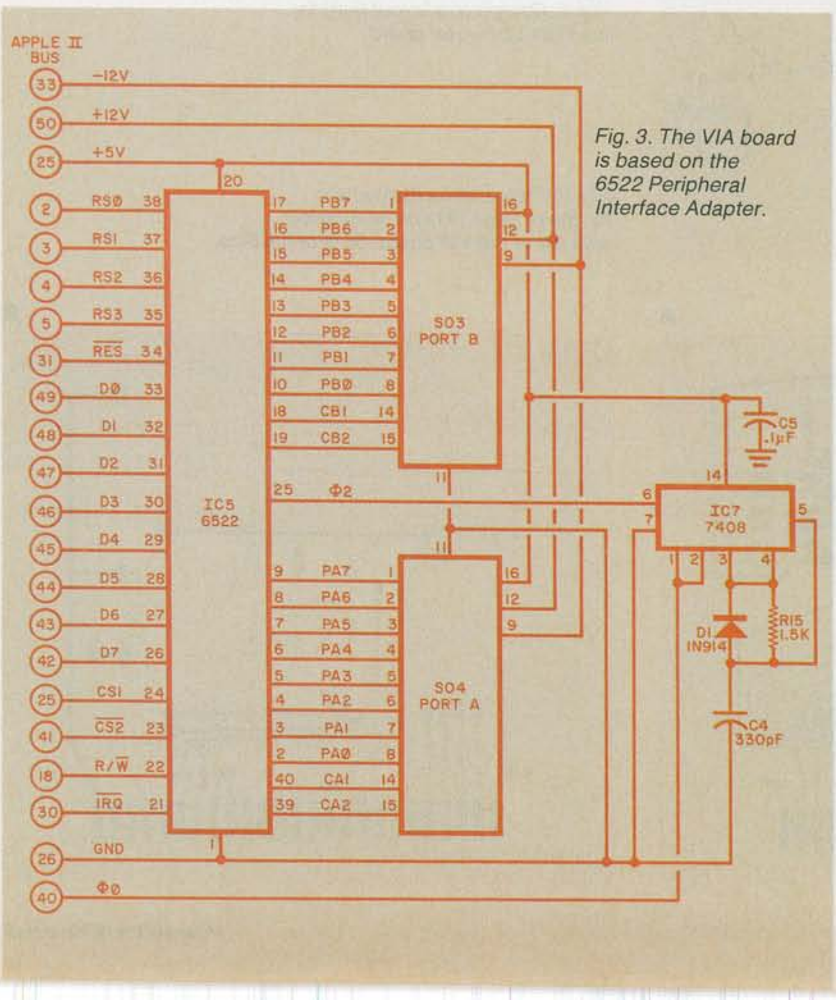


Fig. 3. The VIA board is based on the 6522 Peripheral Interface Adapter.

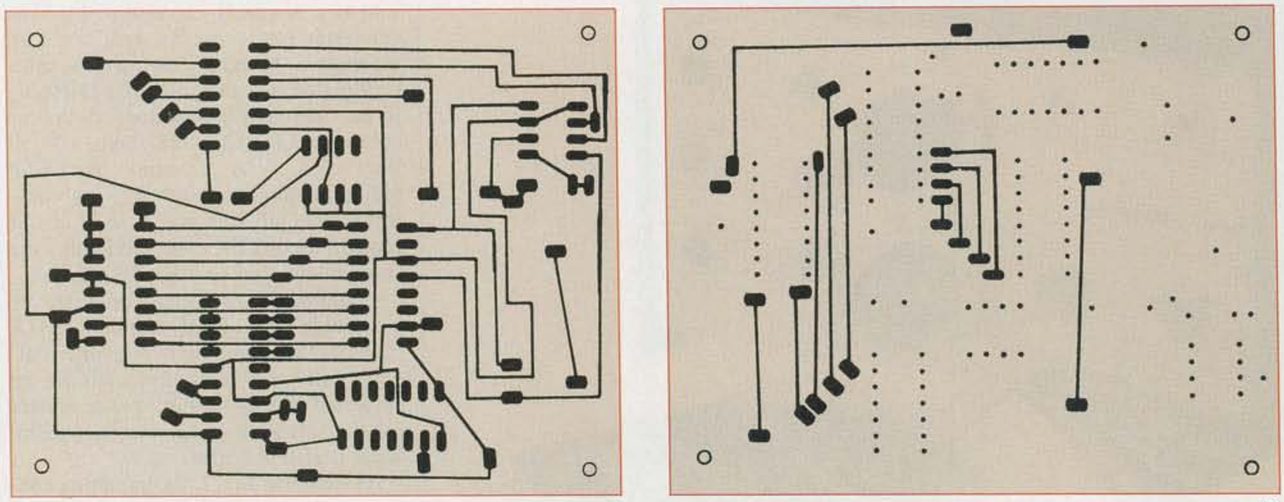
Contained in the Data Converter are a variable-gain signal amplifier, D/A converter with analog and speaker outputs, A/D converter that includes an amplified analog output, and a control panel. A trigger signal for an oscilloscope is also provided.

As shown in Fig. 2, the incoming analog signal at *J1* goes to the inverting (−) input of unity-gain buffer *IC1A*. Potentiometer *R3* is used to preset the zero offset to the buffer. The output from *IC1A* goes to *IC1B*, and the gain of the stage is set by GAIN switch *S1* (gains are 5, 10, 50, 100, or 500). A monitor point or optional output is provided at *J2*.

After amplification, the output at pin 7 of *IC1B* goes to AC/DC selector *S2*. With *S3* set to ON and *S2* set to DC, a negative reference from *B1* is applied to pin 2 of *IC2*. Input range is, therefore, 0 to 9 volts (V_{REF}). Setting *S2* to AC places *B2*, with half the voltage of *B1* (4.5 V), in series with the signal. Hence, with a V_{REF} of 9 volts and *B2* at 4.5 volts, a range of +4.5 to −4.5 volts is obtained, allowing signal peak-to-peak amplitudes up to this level to be digitized.

Conversion time for the synchronous clock oscillator inside *IC2* is about 20 µs with the values specified for *C1* and *R12*. With Chip-Select (CS) pin 16 of *IC2* tied to ground, operation is controlled by Read pin 15. Depending on which port (A or B) of the VIA is used, pin 15 will be controlled by the CA2 or CB2 signal. The eight data lines (D0 through D7) go to pins 6 through 13 of *IC2*. Three-state buffers in *IC2* use the data lines when required, since D/A converter *IC3* also shares the same lines.

D/A converter *IC3* requires no external components to operate. Pins 1 through 8 connect to the data lines, while pins 14, 15, and 16 tie together to provide a 0-to-2.56-volt output at *J5* (DAC) and the top of VOL control *R14*. Normally, +5 volts is applied to pin 11 of *IC3*; if this potential is raised to between 11.4 and 16.5 volts and pin 14 is tied to ground, the A/D output will be in the 0-to-10-volt range.



A B

Fig. 4. Foil patterns (above) are for the pin side (A) and component side (B) of the Data Converter board. They are 86% of full size.

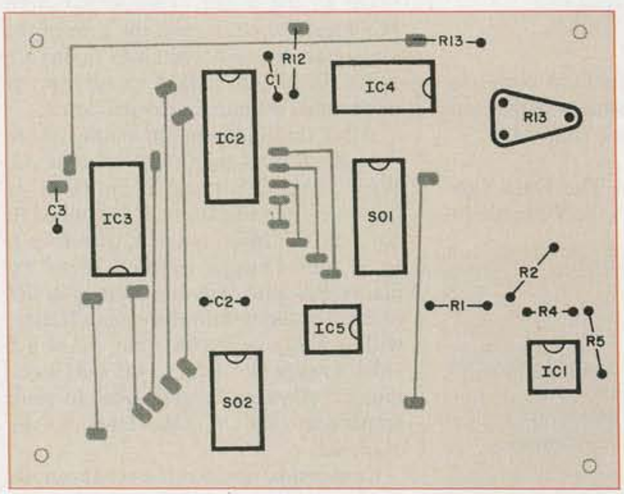
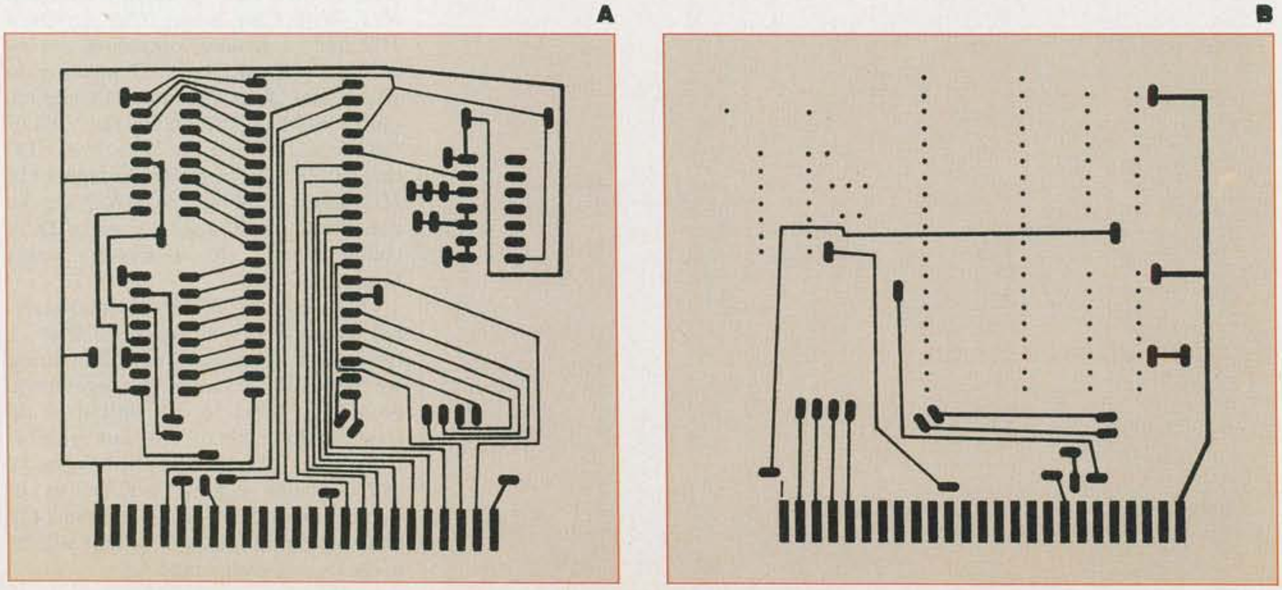


Fig. 5. Component layout (left) for the Data Converter board.

Fig. 6. Foil patterns (below) are for the pin side (A) and component side (B) of the VIA board. 86% of full Size.

A B



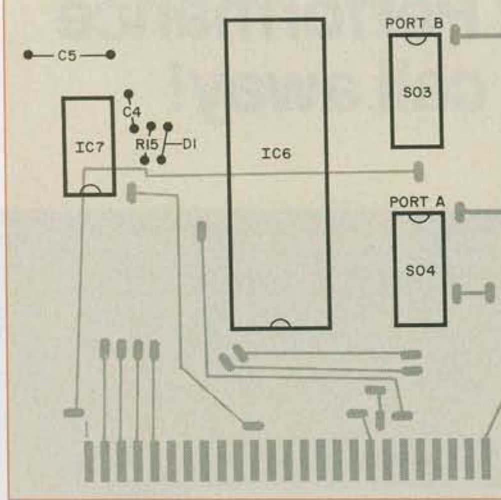


Fig. 7. Component layout for the Apple interface adapter.

Chip Select pin 10 of *IC3* is tied to ground and operation is controlled by the signal at Chip Enable pin 9. One element of open-collector inverter *IC4*, inverts the phase of the CA2 or CB2 control signal before supplying it to pin 9 through load resistor *R13*. Since *IC2* is read when its Read goes low, and *IC3* runs when its Chip Enable goes low, inversion of the common control signal keeps the two ICs from operating at the same time.

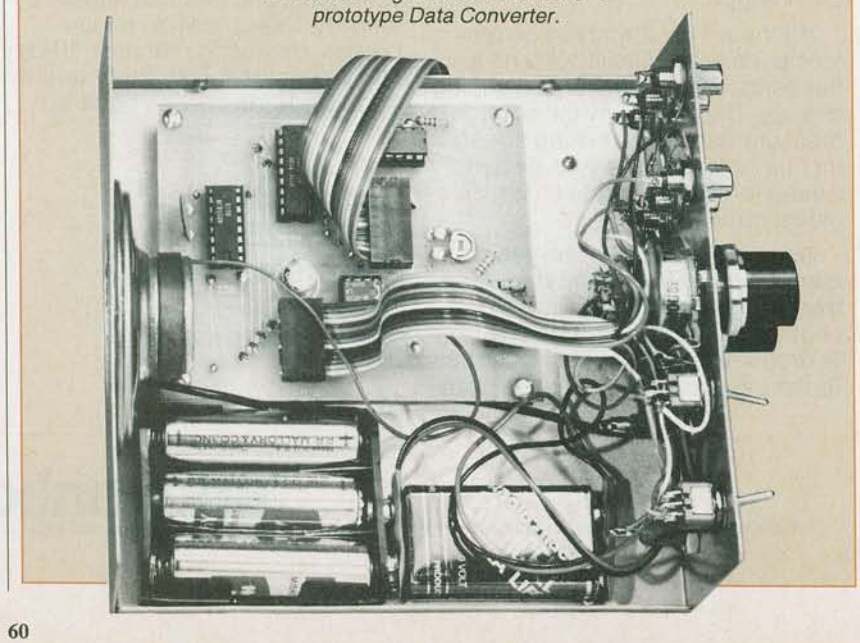
The audio signal selected by VOL control *R14* goes to audio amplifier *IC5*, the output of which is coupled through *C2* to drive a small loudspeaker.

The Data Converter connects to the VIA board through 16-pin DIP header *SO1*, which carries the data, control, voltage, and ground lines. Interconnection between the Data Converter and its front-panel components is via 14-pin DIP header *SO2*. (Connections in the circuit for this header are shown with circles in Fig. 2.)

The VIA board for the Apple II, shown in Fig. 3, is based on the 6522 PIA Peripheral Interface Adapter. Data lines D0 through D7 go through either Port A as PA0 through PA7 with control lines CA1 and CA2 or through Port B as PB0 through PB7 with control lines CB1 and CB2. Each port connects to the following circuitry through connector *SO3* for Port B or through *SO4* for Port A.

Integrated circuit *IC5* expects to receive the phase-2 clock signal from the 6502 CPU in the Apple computer from bus connector pin 40. However, this signal isn't available from the Apple bus or any other easily accessible location in the Apple computer. To overcome this obstacle, phase 0 and the delay introduced by the *IC7* circuit are used to provide the required clock signal for *IC5*. The values specified for *C4* and *R15* cause this circuit to delay the phase-0 clock signal by 180 ns, making the 6522 "think" it's getting the phase-2 clock signal from the Apple computer. A discharge path through *D1* is provided for capacitor *C4*.

Photo showing inside of the author's prototype Data Converter.



Construction. The Data Converter is best assembled on a printed-circuit board, preferably a double-sided design to keep layout area to a minimum and obviate the need for a multitude of jumpers. You can fabricate your own pc board using the etching-and-drilling guides in Fig. 4 and the component mounting diagram in Fig. 5. Sockets are recommended for the ICs, and careful attention must be paid to component orientation during installation. Once this board is wired, it can be mounted in an enclosure of suitable size, with *B1* and *B2* fastened to the bottom of the box via battery holders and quick-set epoxy cement.

The enclosure's front panel can be machined to accommodate *J1* through *J8*, POWER switch *S3*, AC/DC switch *S2*, RANGE selector *S1*, and VOL control *R14*. Use a lettering kit to label the front panel, and install control knobs on the shafts of *R13* and *S1*.

Front-panel components connect to the Data Converter pc assembly through a multiple-conductor ribbon cable. One end of this cable should be soldered to the appropriate lugs on the panel-mounted components, the other end to the appropriate *SO2* pins on the pc assembly.

Assembly of the Apple interface adapter can be on any Apple-compatible prototyping board. Alternatively, you can fabricate your own double-sided pc board, using the etching-and-drilling guides in Fig. 6. Again, during wiring of this board (see Fig. 7 for details), it's recommended that you use sockets for the ICs.

The interface adapter assembly connects to the Data Converter through a length of 16-conductor ribbon cable with 16-pin DIP sockets at each end. This cable plugs into the system between *SO1* on the Data Converter and *SO3* (Port B) or *SO4* on the interface adapter.

(To be continued)