Instructions For Assembling An 82166 HP-IL Converter From Scratch

by Gary Friedman

Those of you wishing to interface your handheld computer or calculator to the outside world require a special interface module that accepts the HP-IL cables in one end and provides up to 16 wires for reading and writing on the other. Although Hewlett Packard still sells a ready-made device which can do this called the 82165A HP-IL/GPIO interface, its $245 cost, large physical size, lack of battery power and absence of two unique handshaking wires make this product a less desirable option.

Fortunately, another solution exists. Although HP has stopped selling its versatile, ready-made 82166 IL Converters, EduCalc still provides the service of selling all the parts necessary to construct one of your own, at a cost of only $83.00. This Technical Note describes how to take these parts and construct a working IL Converter on your own. It requires about two to three evenings to fabricate, but once done a whole world of interfacing applications become available to you, applications that are portable and don't require large physical size or AC power like other computers do. (In fact, I can even recommend a good book describing the basics as well as imaginative uses of this new ability!)

Functional Description

A simplified diagram of the IL Converter appears in Fig. 1. In its default mode, you might think of an IL Converter as being a parallel port on an IBM-PC; it is a box that allows an HP calculator to print to a Centronix-type printer, as shown in Fig. 2. (The numbers in parentheses () refer to the pin numbers of an off-the-shelf unit. If you're building your own IL converter, ignore these numbers.) Each 8-bit ASCII character that the calculator sends out eventually appears on the IL Converter's 8 output wires for a fraction of a second, just long enough for an attached printer to understand what character was sent. The data appears on the wires labeled DA0, DA1, DA2.....DA7, and these 8 wires together can represent any number between 0 and 255 by counting in binary. There is also a 9th wire, called DAVO (which stands for the DAta wires are Valid in the Outgoing direction), which tells the printer that the other 8 wires have meaningful data on them right now. After the DAVO signal appears the printer only has 40 microseconds to latch onto the data; after that the data goes away and the IL Converter replaces it with the next byte the calculator sends.

That's its most basic configuration, anyway. The IL Converter also has the capability to look at information appearing on these wires ("reading") as well as sending information to them ("writing"), making it suitable for collecting data from other peripherals as well. Furthermore, using software commands the controlling computer can program the IL Converter to change its behavior[1]. For example, you can tell the converter to use 16 wires instead of 8 when writing words (enabling it to send data that represents a number from 0 to 65,536), or you could tell it to keep the data on the data bus for longer than 40 microseconds. It can even look for and strip out characters in the data stream (such as a "carriage return/line feed" pair that often terminates input streams from other computers), and you can specify what kinds of abnormal communication conditions you think it should alert your computer about.

With these versatile options, it becomes easy to use the IL Converter to allow a calculator to talk to just about anything, and in fact that's exactly what the designers of this unit had in mind. For more information on how to apply this versatility, you should refer to the IL Converter Technical Manual. In addition, there's a wonderful book called Control the World with HP-IL (which I also highly recommend) which takes you beyond simply interfacing with peripherals and describes home-made circuitry which allows it to turn AC appliances on and off, measure real-world analog signals, have it talk with synthetic speech, answer the phone, and completely automate a photographic darkroom -- All with a battery-powered, handheld calculator. (Of course, since I wrote the book, I may be somewhat biased.)

The parts necessary for constructing your own IL Converter are listed below, and are available through EduCalc:

Stock #92166 KIT - 6 of the 7 unique parts, including:
- HP-IL Panel receptacle
- Pulse Transformer
- HP-IL Interface IC
- Microprocessor with Custom software in on-board ROM
- 4 MHz Crystal
- 56 milliHenry (mH) Inductor

Price: $65.00

Stock #1810-0651 - Discrete component hybrid chip
Price: $18.00

Stock #????? - IL Converter Technical Manual and Technical Manual Supplement

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[1] Programming the IL Converter with the HP-41 requires one of the following extra plug-in modules:

The Extended I/O ROM (P/N 82183), or
The IL Development ROM (P/N 15043).

Price: ~$15.00

Additionally, these other parts will be necessary, and can be picked up at any electronics supply house, including those owned by Tandy Corp.:

Capacitors:
- 1 x 120 picofarad (pF)
- 2 x 10 microfarad (uF)
- 2 x .1 microfarad (uF)

40-pin IC socket
20-pin IC socket

Voltage regulator; 5-volt rating

(optional) 26 push-in terminals

Battery holder; enough to hold 4 AA batteries.

Perfboard on which to mount the components, measuring 3.5" x 4".

Required tools (the smaller the better):

- Soldering Iron, 25 or 35 watts.
- Wire (I find the fine wire used for wire-wrapping to be ideal.) Red, Black, and a third color.
- Wire strippers that remove the insulation without nicking the wire inside.
- Diagonal wire cutters
- Needle-nosed pliers
- An indelible, "mark on anything" fine-point pen.
- A light-emitting diode, a logic probe, or an oscilloscope for troubleshooting purposes.
- A 4011 CMOS Quad 2-input NAND Gate IC for troubleshooting Data Bus B.

Optional tools:

- De-soldering tool; used for when you want to re-do a sloppy connection. Simply apply a soldering iron to the sloppy connection and this device will suck the molten solder away.

- A general purpose Volt-Ohm meter

Basic Precautions

Because the integrated circuits are fabricated using the low-power CMOS process, they are particularly susceptible to static electricity, or 'Electro-Static Discharge' as people with degrees like to call it. ESD can be a problem on very dry days (10-20% humidity), where simply walking across a carpet can generate 35,000 volts in static buildup. To minimize damaging the chips during handling and circuit construction, take these few precautionary steps:

As you sit down to work, touch a part of a metal desk or work lamp to discharge any static buildup you may have accumulated. Keep the cat away from the work area.

Your clothes should be free from polyester fibers; all cotton shirts and jeans not only minimize risk of static discharge but are also more comfortable to work in. Rubber-soled shoes are best, not the type with leather soles.

These suggestions may sound rather restrictive, but they are analogous to the eye goggles they insisted you wear during chemistry lab in high school. These guidelines become increasingly important as humidity levels drop and the frequency of electric shocks becomes noticeable.

Board Layout and Assembly

Construction of the IL Converter will be done in two phases, corresponding to the two different pages of schematics. Phase I (as shown on Schematic page #1) will bring together the IL interface chip, the IL receptacle sockets, the pulse transformer, and the hybrid chip.

Phase II will add the custom microprocessor, giving the unit it's personality and its ability to respond to loop requests. To test out these phases, I will give software examples using an HP-41 and an HP-71; if you own a 75 or a 110, don't bother me.

Before we begin, let's start with parts identification. Fig. 3 shows drawings of what the basic parts look like and identifies key characteristics that you should know about. When installing integrated circuits, for example, look for the special 'dot' which identifies Pin 1. (This also appears in the schematics.) The last thing you want to do after completing the wiring is accidentally install the IC backwards!!

The funny-looking gold-colored part identified in Figure 3 is called the Hybrid chip. It's sole purpose is to reduce the number of parts required, as it combines diodes, resistors, and capacitors that otherwise would have to be installed along with all the other parts. If you didn't order a hybrid chip don't panic, it can easily be substituted by the individual components it was designed to replace. Refer to Schematic 1 (inside the dotted box) for part values and how they are to be connected.

Push-in terminals (listed under optional in the parts list earlier) are handy tie points that can present the 26 I/O lines in an accessible fashion. If they are well spaced and well labeled, external circuitry can access the connections with alligator clips or soldered wires, and all without the tedious wire counting that was needed with HP's original 34-pin connector.

If you can't find push-in terminals or discover that they don't seem to fit the tiny little holes in your perfboard, a low-tech solution is suggested: use slightly thicker telephone-type hook-up wire, woven in and out as in Fig. XX, as a substitute. This was the method used to produced the photo.

Fig. 4 shows the layout of parts on the board. Looks, straightforward, right? OK, now we can start.

Take 4 components: the pulse transformer, the hybrid chip, and the two IC sockets (not the ICs themselves; these will be put in last) and place them on the board in the same configuration shown in Fig. 4a. Use a piece of scotch tape or a drop of rubber cement to affix these to the perfboard; it will keep the components from falling off the board when it is turned upside-down during soldering.

Using an indelible marking pen, mark the upper-left-hand-corner pin on both IC sockets; this will be referred to as pin 1. (See illustration.) Many IC sockets already contain an indicating notch similar to those found on the ICs; look for it and mark it on the perfboard.

Then, turn the board upside down and mark the pin 1 position in a similar fashion. (MAKE SURE IT'S THE SAME PIN!) This way, when the board is upside down and everything looks backwards, you'll know where everything is and know from which pin to start counting. In addition, label the ICs so you'll know what's where on the bottom, as well as pins 1, 14, 15, and 28 on the first IC and pins 1, 20, 21, and 40 on the second to make finding the pin you want even easier. (See Figure 4b.) These simple steps will help you avoid 50% of all wiring errors and speed up construction to boot.

Phase I

(Notice how I conveniently omit the section on proper assembly and soldering techniques.)

- 1st, hook up the power (+5v and ground) to all the parts that require them. I find it helpful to use only red wire to link together all points requiring 5v, and black wire to connect together everything with a GND or CIRCUIT GROUND symbol (that funny little symbol.) Notice there are two types of ground symbols in the Phase I schematic: Circuit Ground (parallel lines of diminishing size) and ESD (Electro-Static Discharge) Ground. Since they are both grounds, they should be connected together. However, make sure you connect them AT EXACTLY ONE POINT.

- Next, using the third wire color, start the point-to-point wire connections.

- As you complete each point-to-point solder connection, mark the schematic with a pen to reflect this progress. When you think you're finished, a quick glance will indicate if any wires are missing.

Phase II Construction [Abolish this 'phase' stuff.]

Regretfully, there is no method of testing the circuit at the Phase I point. Assemble the Phase II schematic the same way you accomplished Phase I.

Circuit Check Out

- At the end of Phase I construction (actually this is important when assembling any circuit in general), all the wiring should be 'buzzed out' before any ICs are plugged in or any power is applied. Get the help of someone else to sit down with you and your ohm meter, and have that person meticulously read out each wire's starting and finishing point while you faithfully check for continuity between those two points.

- Check to see that power has been wired to the proper points.

- Check to insure that there is no connection between an arbitrary +5v point and a ground point.

- If everything looks OK, then go ahead and plug in the ICs (make sure pin 1 is in the right place!) and plug a computer into the HP-IL receptacle.

- Attach your battery leads to pin 1 and 2 of the voltage regulator and IMMEDIATELY perform this quick check using the computer:

    71: Do a 'RESTORE IO'.
    41: Do a '1 SELECT'.

If the computer comes back with a 'LOOP BROKEN' or similar error message, IMMEDIATELY REMOVE POWER from your circuit and start to check for wiring errors. During this troubleshooting stage it may be helpful to remove the ICs again so you can check for continuity or shorts without the ICs interfering with the tests (or without your test equipment zapping the chips!).

Once the above step is performed successfully, the next step is to run some test software that generates a cyclic "test pattern", and examine all 16 data lines with an LED or a logic probe (or perhaps even an oscilloscope) to make sure all the lines are healthy.

Behavior Explanation

Run the following programs:

On the 71:

```
5  ENDLINE "" @ A=DEVADDR("INTRFCE")
10 SEND UNT UNL LISTEN A MTA DDL 0 DATA 64,0,216+4-128-64 UNT UNL
20 OUTPUT :A; CHR$(255) & CHR$(255) @ WAIT .1
30 OUTPUT :A; CHR$(0) & CHR$(0) @ WAIT .1
40 GOTO 20
```

Lines 5 and 10 set up the initial conditions: ENDLINE "" prevents the Carriage Return/Line Feed that would normally accompany anything sent out. The next part of that line looks for the loop position of the first device that describes itself as an interface class device, and assigns that loop position to the variable A. As it so happens, the IL Converter's microprocessor has been programed to respond as an interface class device.

Line 10 programs the IL Converter via the Device Dependent Listen (DDL) command to set itself to 16 bit mode, and ignore all handshake lines.

Line 20 outputs two bytes comprised of all 1's (CHR$(255)), which set all 8 bits of Data Bus A and all 8 bits of Data Bus B to "1" for a millisecond; line 30 sends two bytes of all 0's setting all 16 of these same lines to "0". On an oscilloscope, this ought to appear as a square wave. (It won't; read on!)

On the 41 with an Extended I/O Module:

TBP [To Be Programmed.]

On the 41 with an HP-IL Development ROM:

```
LBL TEST
"HP82166"
FINDID
STO 1
X<0?
GTO 2
7
BUFSIZX
0
PT=
AIPT
64
```

```
X-BUF
0
X-BUF
28
X-BUF
0
PT=
RCL 1
LAD
0
DDL
3
OUTBUFX
UNL
RCL 1
LAD
LBL 1
255
OUTBIN
OUTBIN
0
OUTBIN
OUTBIN
GTO 1
LBL 2
TONE 0
"NO RESPONSE"
AVIEW
END
```

Figure XX shows a simple graph of what the signals should look like when the test software is run. That is, they should be "high" (=5v, the default state) most of the time, except for when a "0" is written out, in which case it drops to zero volts for a brief interval. As can be seen in Fig. 5, the DAVO handshake line will pulse at twice the rate of the lines belonging to Data Bus A. Data Bus B, on the other hand, posesses such a noisy output that it's difficult to determine what it's doing.

(If you're observant, you'll notice that Data Bus B behaves this way even when the test software has stopped running.)

Verifying proper behavior on Data Bus B is somewhat more difficult, since it is used for inter-chip communication as well as I/O. To filter out only those logic swings you're interested in, you must employ the use of an three NAND gates as shown in Figure. 6. This simple circuit using only 1 4011 IC simply lets through all bits where DAVO (Data Valid Out) is ="1", and blocks out everything else. Putting a logic probe or LED at the output of the third NAND gate should show behavior very similar to that of Data Bus A.

Other Features

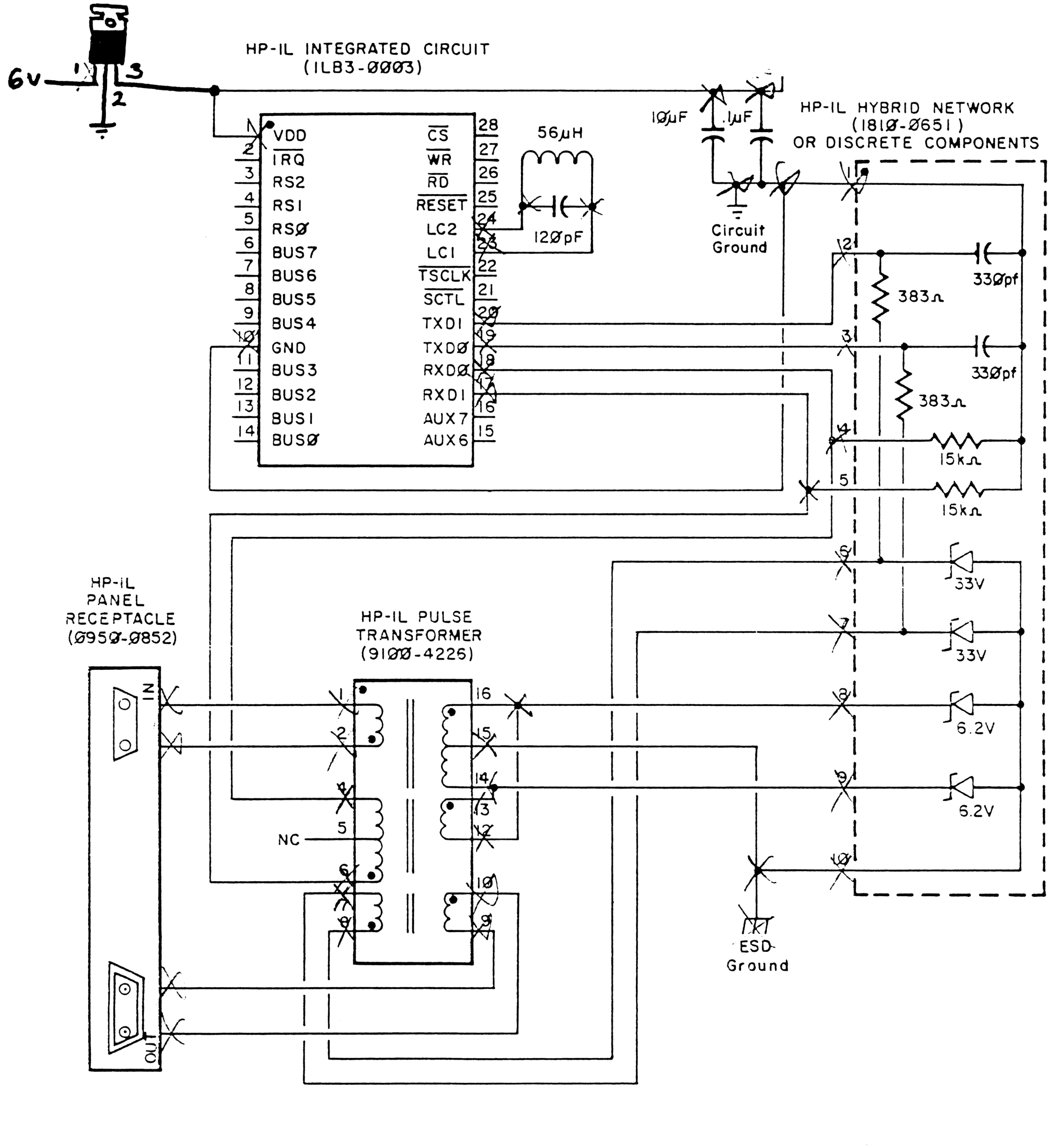
A copy of the IL Converter Technical Manual is included in this package; now that the basic unit has been proven functional, this manual can be consulted to learn more about the unit and common interfacing applications.

[Include an IL Converter manual with this, please.]

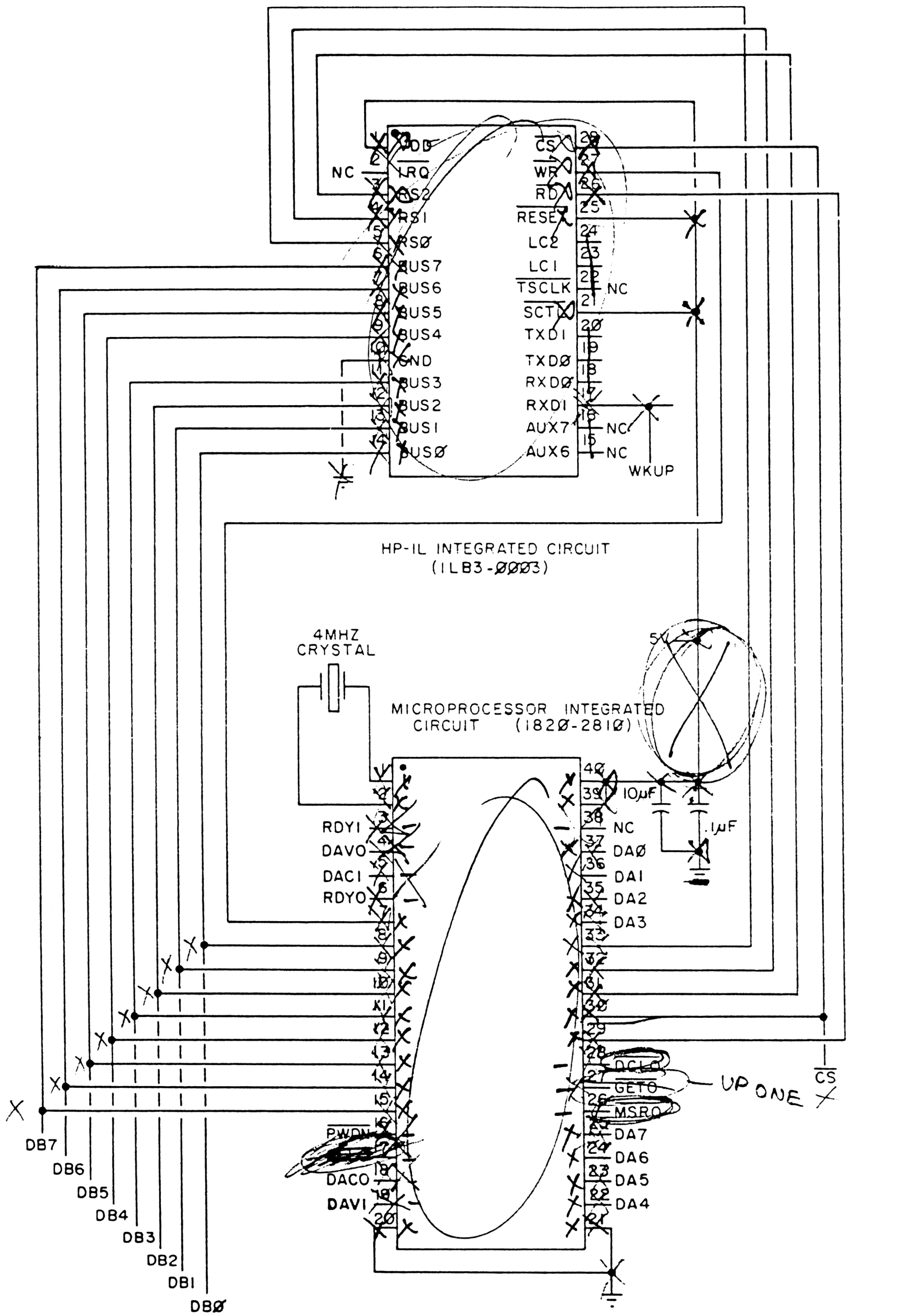
1) Converter doesn't respond to signals; controlling computer errors out with "Transmission Error" or "Loop Broken"	1) POWER DOWN IMMEDIATELY and check for faulty wiring. Eas way to do this is to carefull remove all the ICs and take a ohmeter and check all the pow and ground connections to all critical components. Also ch for a short circuit between p and ground.
2) Can't get Data Bus B to behave properly.	2)

TROUBLESHOOTING SECTION WILL BE COMPLETED, + THE 2 PAGES OF SCHEMATICS (NEXT PAGES) WILL BE 'NEATENED'.

— GARY

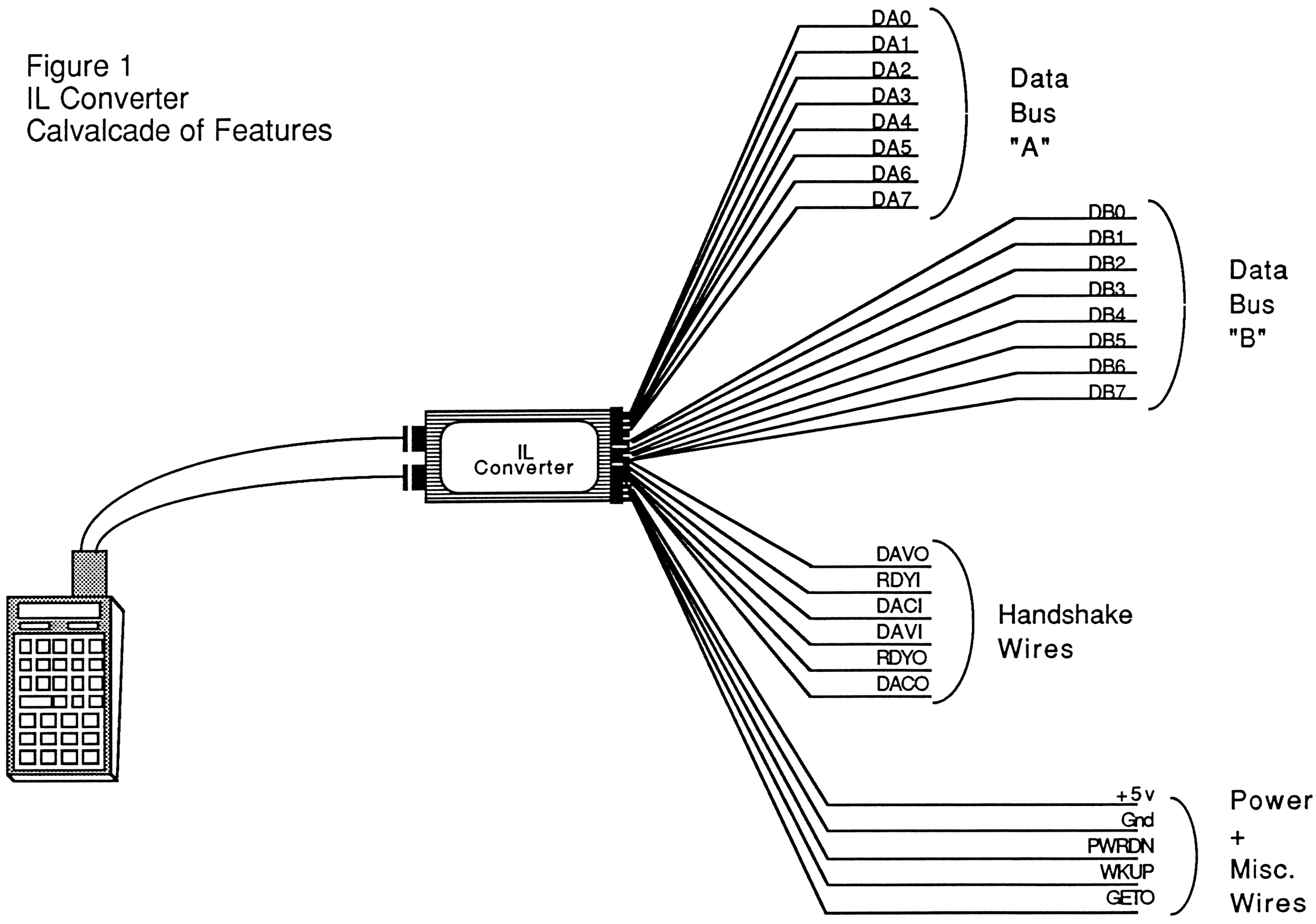


SCHEMATIC
~~Figure~~ 1: HP-IL Interface Connection Diagram



Schematic
~~Figure~~ 2: HP-IL Converter Microprocessor Connection Diagram

Figure 1
IL Converter
Calvalcade of Features



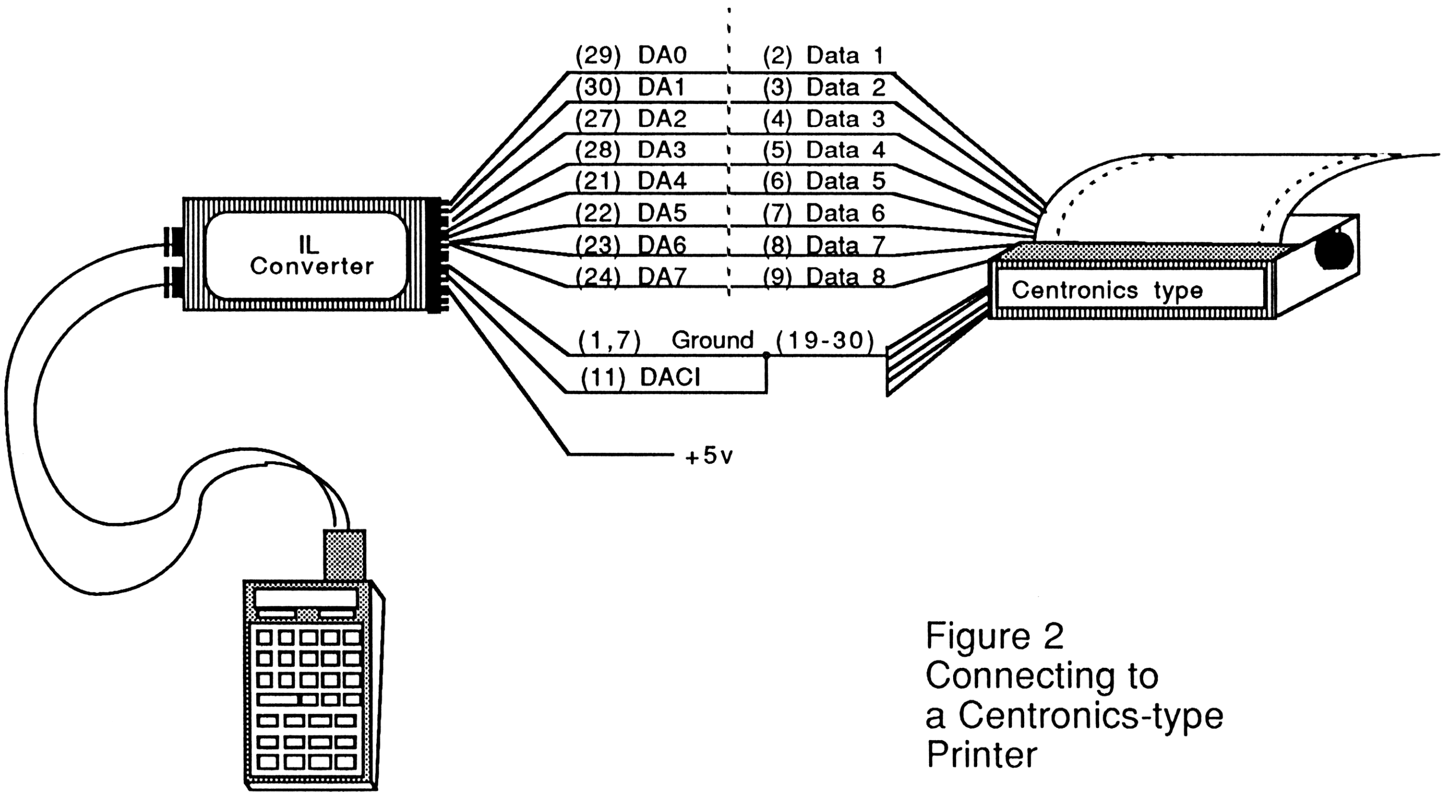


Figure 2
Connecting to
a Centronics-type
Printer

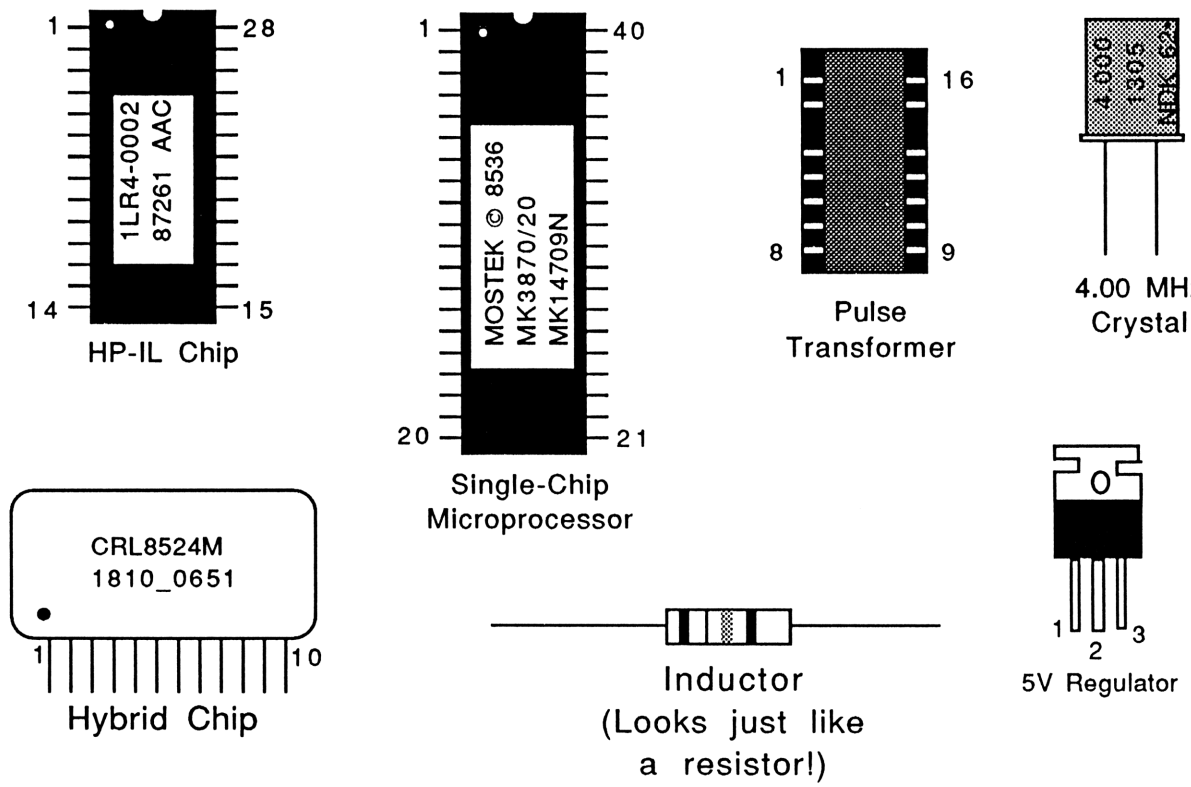


Figure 3
Parts Identification

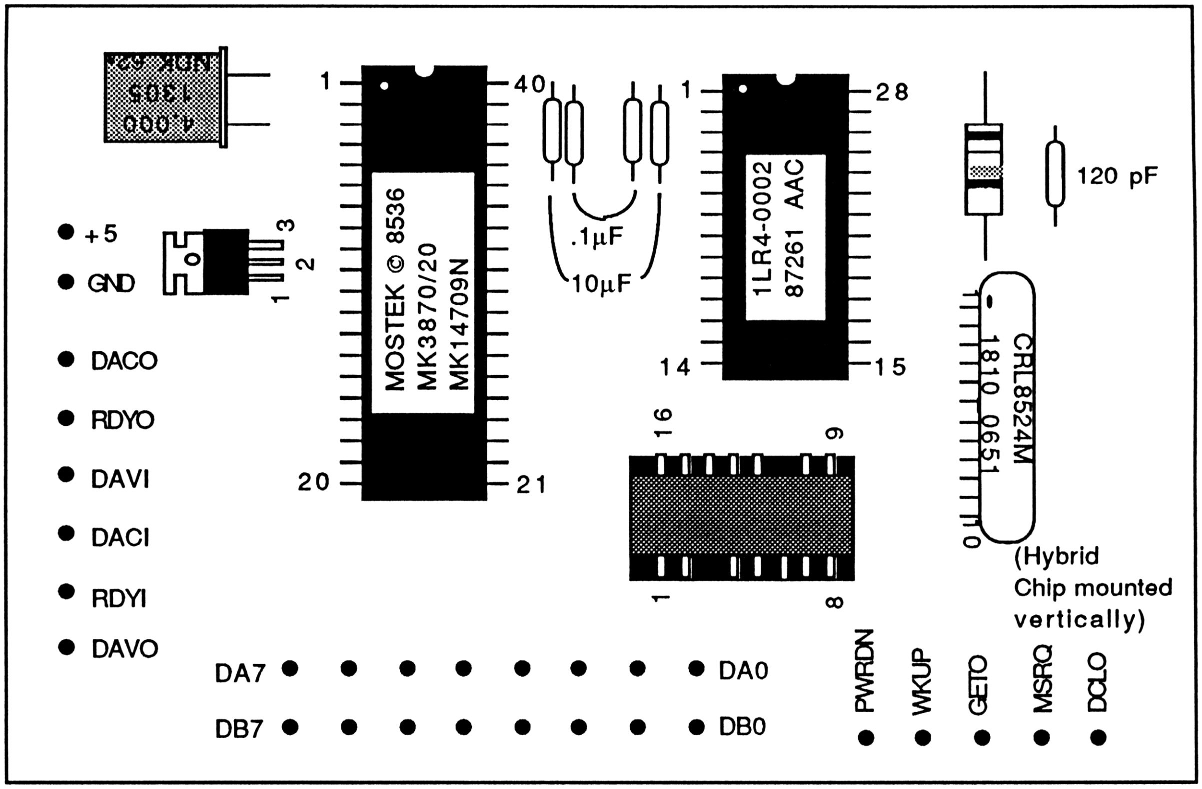


Figure 4a
Component layout as seen from top.

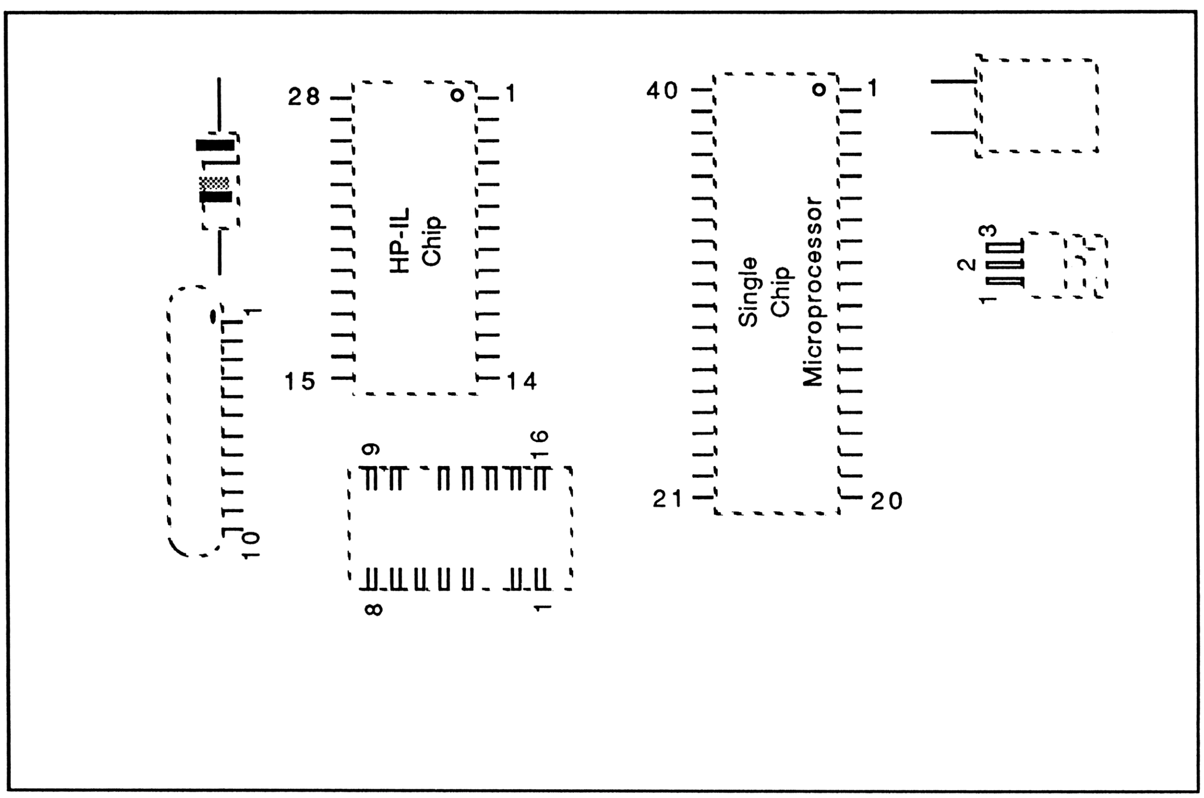


Figure 4b.
Board layout as seen from bottom.

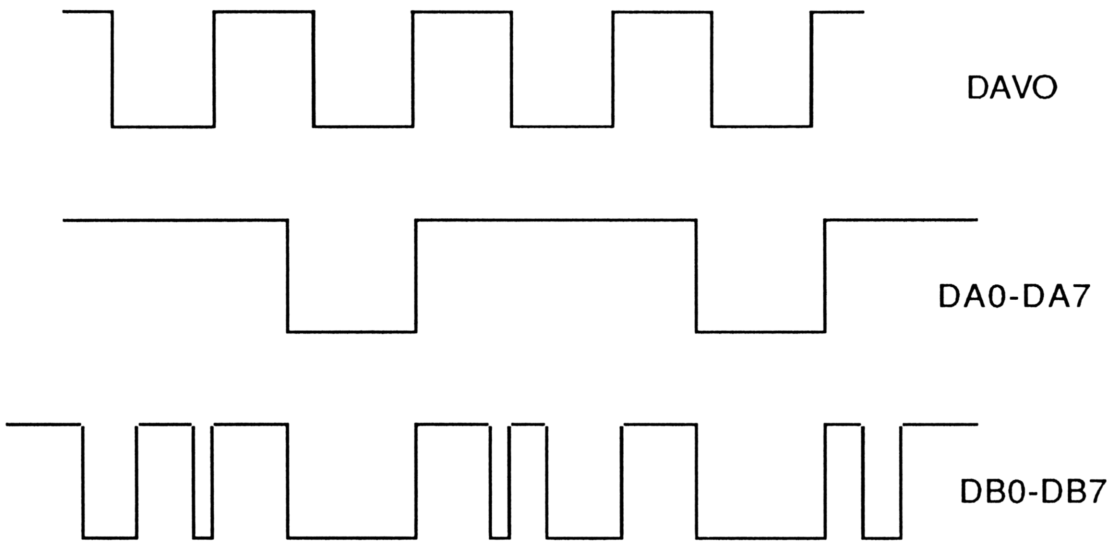


Figure 5
Test Program
Results

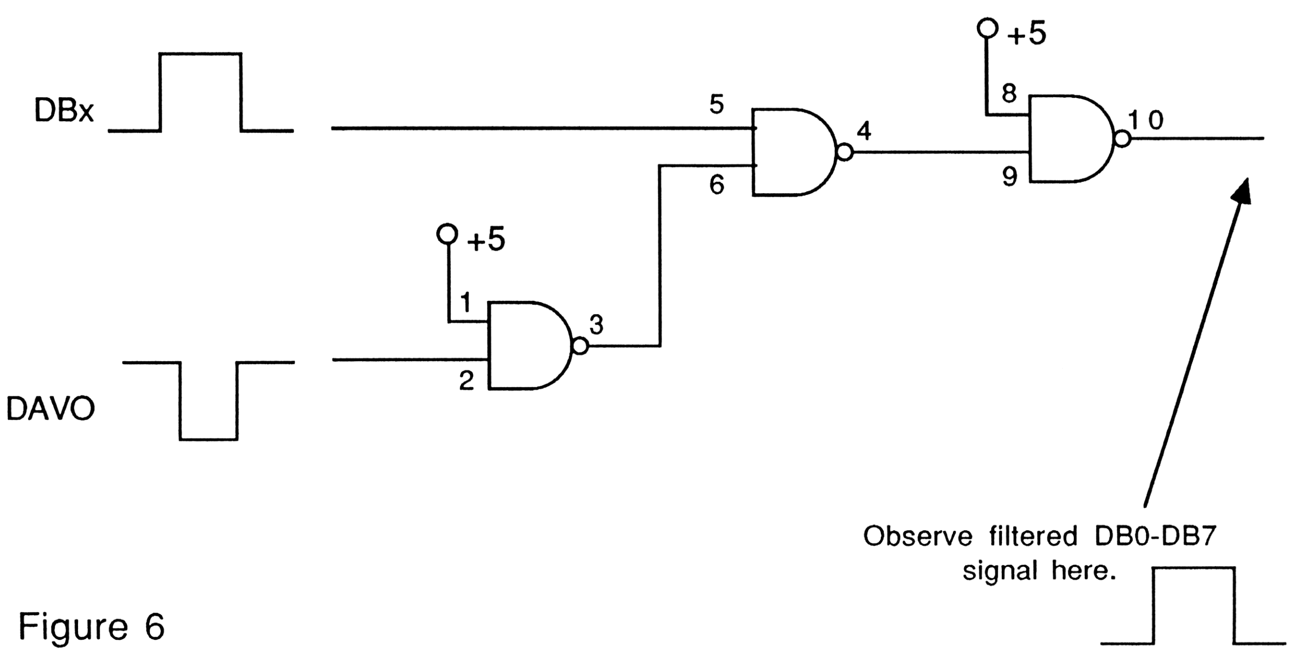
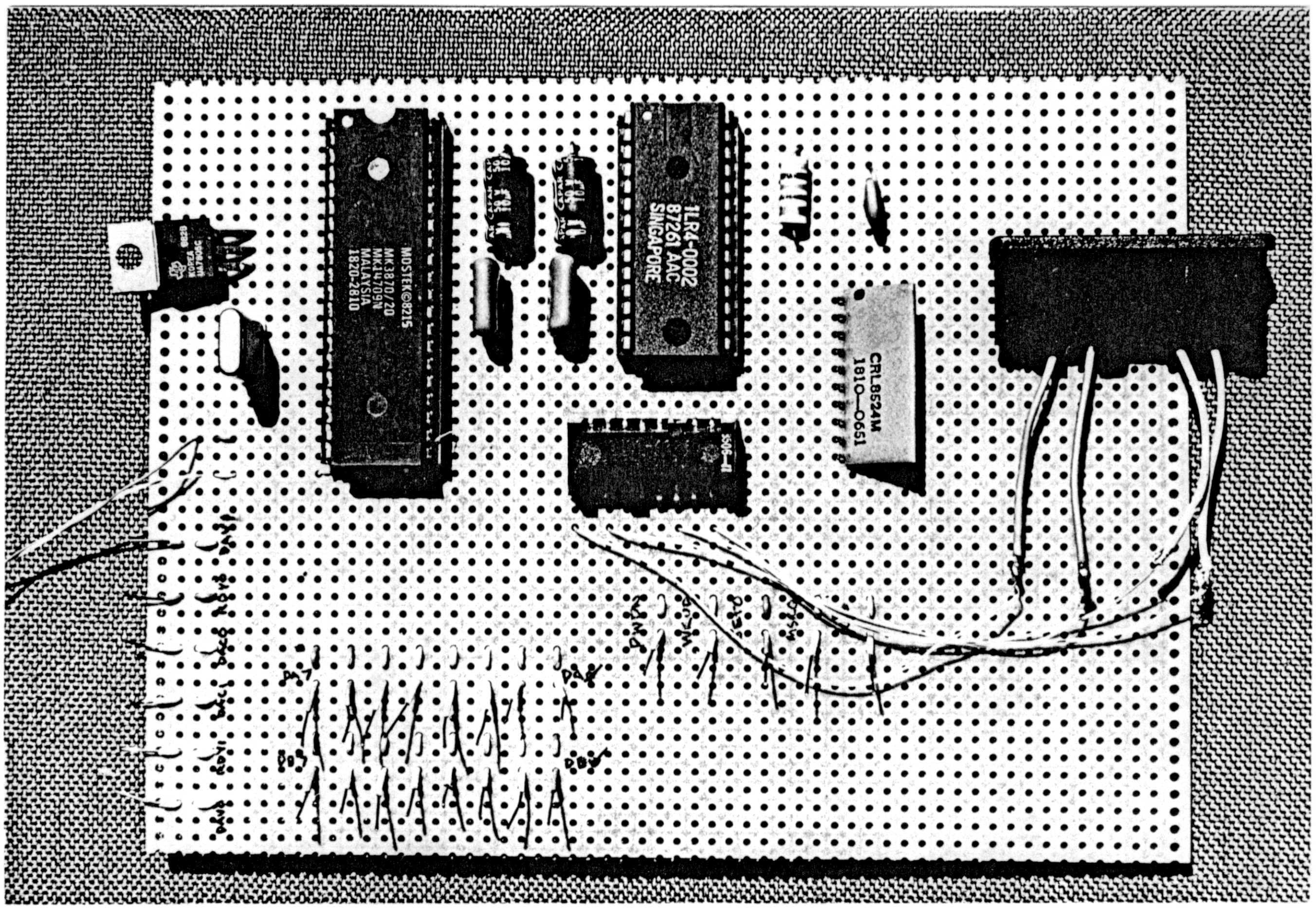


Figure 6
How to filter out the noise
on Data Bus B and see
just the data.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