DSE 'Discovery Series' Construction Project:

# PARALLEL PORT INTERFACE

Latest release in the new Discovery Series of learning kits from Dick Smith Electronics is this low cost interface, which allows a personal computer to monitor and control a wide variety of equipment via its parallel printer port. It provides two analog outputs, eight digital outputs and 10 analog inputs — enough to more than satisfy most requirements. The complete kit is available from DSE's stores as Cat. No. K-2805, priced at $42.50.

If you are a creative person with a computer, then there's sure to be some project at home or work that could use this project. It acts as a 'real world' interface for your computer, allowing it to directly sense data, process it and use the results to directly control — rather than just processing data fed in manually.

In combination with readily available transducers (sensors) the computer can monitor physical parameters such as temperature, pressure, movement, light intensity, etc, process the information and then control physical things using relays, solenoids, motors and so on.

The interface works via a standard Centronics (parallel) printer port and, because of its low power consumption, can be operated from a 9V battery (not included in the DSE kit) or any DC supply in the range 7.5-25V. It can monitor 10 analog voltages, drive eight digital outputs and generate two variable analog voltages. It can also read its own power supply voltage, to make possible 'low battery' warnings, and the power supply can even be switched on and off by the computer.

Sample programs are provided which allow you to control the interface immediately. You can expand the programs later to suit your own needs.

Connection to the interface is made easy by PCB mounted plugs and sockets, which are provided in the DSE kit. A 25 pin male 'D' to 25 pin male 'D' connecting cable, preferably a shielded type, is required for connection to the computer printer port. The kit PCB is designed to fit in a Dick Smith Electronics 'Zippy' box Cat. No. H-2851. The printer cable and box are not provided with the kit.

The interface circuit can be divided into a number of functional blocks. There is a 24-bit shift register/latch, consisting of IC's 1-3, which receives three eight-but bytes of data from the computer and holds it for controlling the interface outputs.

Two of these bytes, stored in IC1 and IC2, are used to drive a pair of digital to analog converters (DAC's) which convert this data into analog voltages at analog output terminals 0 (SK3) and 1 (SK2) respectively. The third output data byte, stored in IC3, is fed to buffer IC5 which allows each bit to control one of eight high current digital outputs available at connector SK4.

The analog input circuitry is based around IC4. This is an analog-to-digital converter (ADC) with 12 addressible inputs (A0 - A11), and serial interfacing on the digital side.

The computer is therefore able to instruct the ADC chip (via pin 17) regarding which of the analog inputs is to be selected, after which the ADC performs a conversion and signals the computer that the digital data is ready, via the EOC output. The computer can then retrieve the data serially from pin 16.

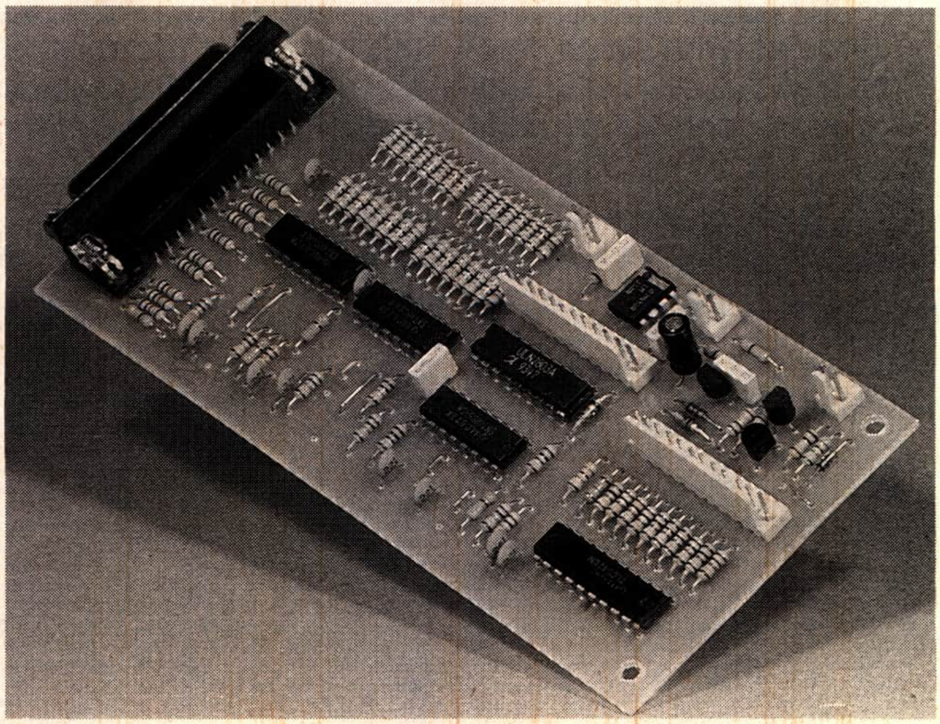
Note that 10 of the external analog inputs of IC4 are used for the analog inputs of the interface, while the final external input (A10) is used to allow the computer to monitor the interface's own battery voltage via resistive divider R65/R66. The twelfth input is connected internally, as described later.

## The printer port

Before describing the functional blocks in more detail, it helps to know how the Centronics printer port is controlled. The port has 25 lines, some of which are for signals and others for ground or signal return paths. The signal lines are either read-only (input to the computer) or write-only (output from the computer) and use 5V (CMOS or TTL) logic.

In the computer, three addresses in I/O space are required to completely access the printer port. The first address is called the *base address* which is usually 378 (hex) for printer port 1 (LPT1) or 278H for LPT2.

The second address is (base address



+ 1) and the third address is (base address + 2). At each of the three addresses there is an eight bit byte stored, with bit 0 being the least significant bit (LSB) and bit 7 the most significant (MSB).

Every signal line on the port, whether it is used for read/input or write/output, is allocated one particular bit at one of these three addresses, the logic state of the bit indicating the state of the wire (0 or +5V). A few of the lines use negative logic — i.e. logic 1 corresponds to 0V and logic 0 to +5V. Table 1 shows the significant bits at each of the three addresses, and the functions these are used for, both normally when the port is used to communicate with a printer and in when it is communicating with the interface described here.

As an example of how the interface is controlled from a program written in QBASIC, the following short command sequence is used to switch the power on and enable the output of IC1:

```
BASE0 = &H378
OUT BASE0, &H80
OUT BASE0 + 2, &H01
```

Here the first line defines the base address of the printer port, as 378H. The second line then sends 80H (binary value = 10000000) to base address 378H, which sets data bit 7 of the port and switches the interface's power on. The third line then sends 01H (binary value 00000001) to address 37AH (base+2), which sets bit 0 of this data byte. As you can see from Table 1 this causes Strobe line 1 to be taken to 0V, as this line uses negative logic. However this line is actually used to enable pin 13 of IC4, which is an active-low input — so the desired effect is achieved.

The printer port output data is stored in latches, so the commands do not have to be repeated to keep any wire in a particular state.

**Table 1**
**Printer Port Wire Allocations**

| Address | Bit | Wire | Direction | Kit Function | Printer Function |
|---|---|---|---|---|---|
| base | 0 | 2 | write | IC1 serial data input | Data bit 0 |
| base | 1 | 3 | write | IC1 - 4 Clock | Data bit 1 |
| base | 2 | 4 | write | Load IC1 latch | Data bit 2 |
| base | 3 | 5 | write | Load IC2 latch | Data bit 3 |
| base | 4 | 6 | write | Load IC3 latch | Data bit 4 |
| base | 5 | 7 | write | IC4 chip select(-) | Data bit 5 |
| base | 6 | 8 | write | IC4 address input | Data bit 6 |
| base | 7 | 9 | write | Power on | Data bit 7 |
| base+1 | 3 | 15 | read | not used | Fault(-) |
| base+1 | 4 | 13 | read | IC4 data out | Select |
| base+1 | 5 | 12 | read | not used | Paper empty |
| base+1 | 6 | 10 | read | IC4 end of conversion | Ack.(-) |
| base+1 | 7(-) | 11 | read | busy | not used |
| base+2 | 0(-) | 1 | write | IC1 output enable(-) | Strobe(-) |
| base+2 | 1(-) | 14 | write | IC2 output enable(-) | Auto feed(-) |
| base+2 | 2 | 16 | write | not used | Init.(-) |
| base+2 | 3(-) | 17 | write | IC3 output enable(-) | Select In.(-) |
| | | 18-25 | | 0V | 0V |

**NOTES:**
1. Normal base addresses are; LPT1 = 378H
LPT2 = 278H
2. (-) next to the bit no. means if the bit is set to 0 then the wire is at +5V.
3. (-) next to the function means the function is activated by 0V.

## Input conditioning

The devices in the computer that drive the printer port outputs may be either TTL or CMOS IC's. CMOS devices, such as this interface uses, cannot be directly driven (reliably) from TTL outputs because the logic 1 output voltage of a TTL device can sometimes be lower than the logic 1 input voltage required by CMOS devices.

In this project, this is avoided by adding 'pull-up' resistors R12-19 to the interface inputs, to ensure that the input voltages fall within the acceptable CMOS input range.

Another problem which has to be allowed for is that the cable connecting the printer port to the interface may pick up interference, especially if it is unshielded or running close to some strong electrical interference. The sort of noise that is likely to cause problems are short duration voltage spikes from arcing electrical contacts of equipment connected to the mains.

To suppress these spikes, series resistors R2-11 and shunt capacitors C2-11 have been added. An adverse effect of this sort of suppression is that it slows down the rate at which the wanted signals can change, by about 200ns. This effect can be ignored when using BASIC programs, and in any case it can be compensated for by providing suitable program delays.

## Interface details

For the control of so many inputs and outputs, the interface designer chose to use serial rather than parallel data transfer between the computer and the interface board. Serial data transfer requires less wiring, less hardware and consequently less PCB space.

Data from the printer port to control the 10 interface outputs (analog outputs 0/1, and digital outputs 0-7) is initially loaded via pin 2 of DB25 connector SK6 into the series-connected shift registers IC1-3, via pin 14 of IC1. The eight-bit shift registers in IC's 1-3 have their serial inputs at pin 14 and serial outputs at pin 9 (as well as an eight-bit parallel output), which allows the three to be connected in series as a single 24-bit serial in/parallel out shift register. Data is moved through the shift registers one bit at a time by clock pulses applied simultaneously to pin 11 of all three devices.

The clock inputs are normally held at 0V, and generating a clock pulse involves applying logic 1 to pin three of the printer port, and then removing it with the next command. Delays involved in the processor carrying out these instructions normally ensure an adequate resulting width of the clock pulse, or of similarly generated signals.

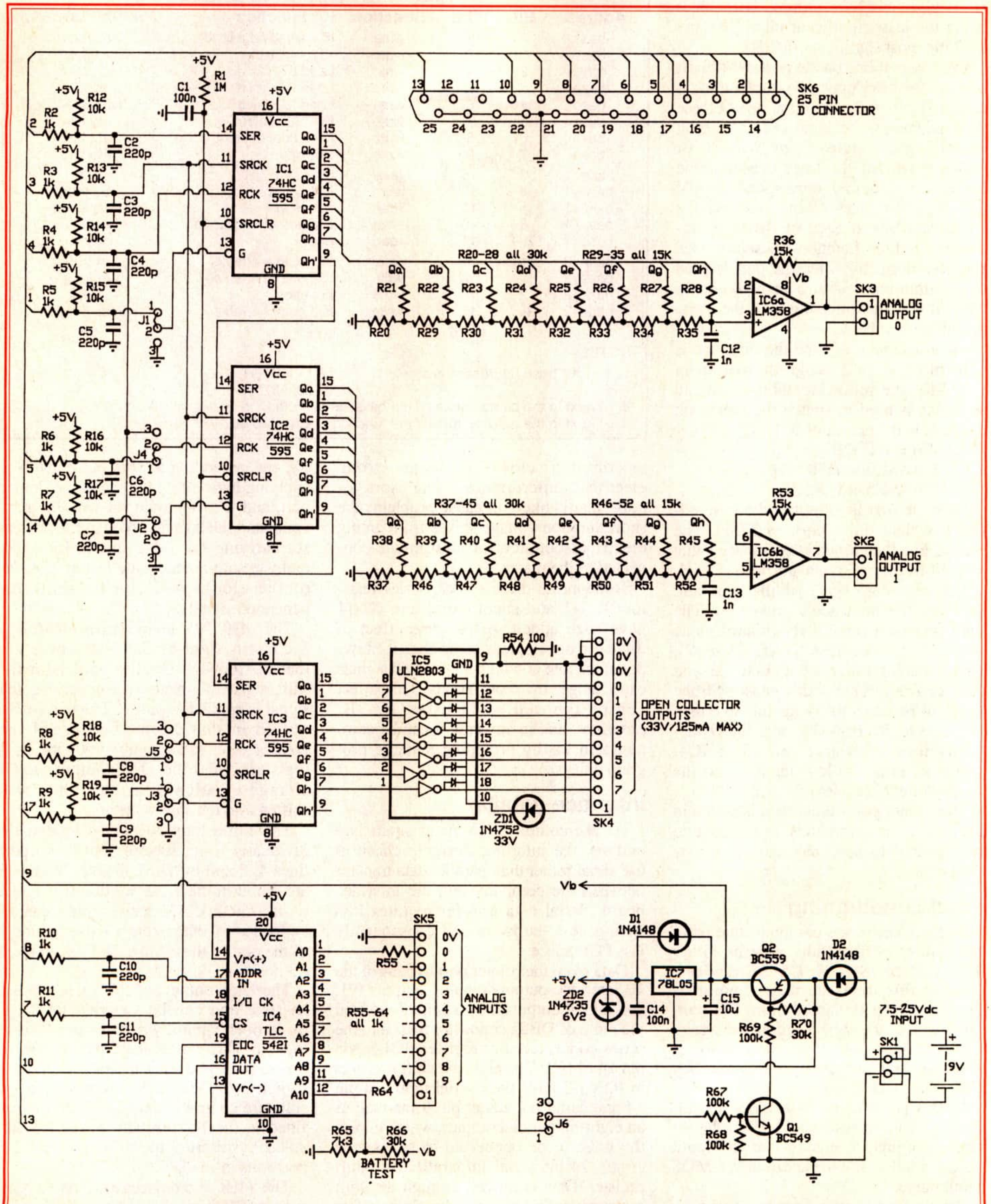
The 74HC595 devices used for IC's 1-3 contain eight-bit latches. These are loaded from the parallel outputs of the shift registers whenever a positive-going signal is applied to pin 12. Latches are required in this circuit because if the DAC's were fed directly from the shift registers, then the DAC output would change erratically as new data was shifted into the shift registers.

The three latches can be loaded individually using separate pulses on port lines 4, 5 and 6 (SK6), if links J4 and J5 are wired in the 1 - 2 position (as shown on the circuit). Alternatively they can all be loaded together from a pulse on line 4 of the port, if these links are fitted in the 2 - 3 position.

The latch outputs of the 74HC595 are tri-state and can be switched off, i.e.. made open circuit, whenever pin 13 is at logic 1. This causes the DAC outputs to go to 0V and the digital outputs to switch off. This facility is available for software control if links J1, J2 and J3 are fitted in the 1-2 position, or can be disabled by inserted these links in the 2-3 positions instead.

The 74HC595 devices also have a reset facility. Whenever pin 10 is at logic 0 the registers are reset to contain all 0's, while when this pin is at logic 1 they are free to accept data.

# 'DISCOVERY' SERIES PARALLEL PORT INTERFACE




***Although it may look a little complex from the schematic, the interface hardware is relatively straightforward and involves only a small number of ICs. Chips IC1 to IC4 perform the serial input and output functions.***

In this circuit the reset inputs have all been connected in such a way that when the power is applied to the circuit, reset occurs until C1 charges via R1. In other words, the registers are reset during power-up, but then allowed to accept data from the PC port.

## D-to-A converters

The eight-bit digital to analog conversion is carried out by resistor networks R20-35 and R37-52, which are known as R-2R 'ladder' networks because only two values of resistor are used, having values in the ratio 1:2.

The analog output voltage (Vout) is related to the digital output (N) by the following formula (Vcc in these formula is the +5V supply rail voltage, not the LM358 supply voltage):

Vout = N * Vcc/256

where Vcc is the +5V supply rail voltage of IC1 and IC2, not the supply voltage of IC6. So in this case the output voltage is approximately equal to:

Vout = N * 20mV

In other words, the output voltage cannot be varied continuously, but in minimum increments of 20mV. These steps and any other 'glitches' which may occur at the output of the DAC network, are rounded off or filtered out by capacitors C12 and 13, and then buffered by unity gain amplifiers IC6a and IC6b before appearing at the output terminals. The final output voltages vary from 0V to +5V, in 20mV steps.

Before connecting a load to the analog outputs, it should be noted that the outputs should be used as current *sources* rather than as current *sinks*; i.e., they work best into a resistive load connected to ground. The reason for this is that the LM358 negative supply is at 0V, and the output voltage cannot reach 0V when sinking even small currents. Whereas because the positive supply is at least 1.5V above 5V, the outputs can reach 5V for output currents up to at least 20mA.

Another reason for making supply for IC6 greater than 5V is that the operating voltage range for the LM358 inputs is from 0V to (Vcc-1.5V). The output from the R-2R resistor network can reach +5V, and so the positive supply for IC6 has to be at least 6.5V.

## Digital outputs

The eight output bits from IC3 are fed to eight separate buffer amplifiers, all contained within IC5, which is a ULN2803.

These buffers act as switches connected between the output and ground, each using a single stage Darlington transistor configuration with an open collector output. When the input is at +5V the switch is on, and when the input is 0V the switch is off.

To protect the output transistors, the outputs are all connected via separate diodes inside the IC to a common point which appears at pin 10. By connecting a zener diode between this point and the IC ground, the voltage at the outputs is prevented from exceeding the zener voltage (plus the diode forward voltage drop).

If a transient voltage higher than 33V appears on the output, as when switching relays or other inductive loads, the zener conducts and prevents the output voltage from exceeding approximately 33V. This method of protection does not significantly increase the release time of a relay connected to the output, as would occur with a diode across the relay coil. The voltage that the outputs of the ULN2803 can withstand without protection is 50V.

The total current flowing through the ground pin of IC5 can reach 4A if each output has 0.5A flowing into it. To prevent heavy currents from being directed through the thin ground tracks on the PCB, the return paths for the digital loads must be connected to the 0V terminals of the digital output socket SK4, which can then be connected externally to the (-) supply terminal of the interface power supply.

In the event that the ground connection to SK4 becomes disconnected, resistor R54 (100 ohms) prevents damage to the board by isolating the main circuit ground from the digital output ground. The input currents to IC5 also flow through this resistor, but it is small enough not to effect normal operation.

### Interface specification

| | |
|---|---|
| **Analog outputs (2):** | |
| Voltage range | 0 - 5V unloaded |
| Resolution | 8 bits (20mV/step) |
| Source current | 20mA approx. |
| Sink current | 5uA for 20mV (1 LSB) error at 0V out |
| **Digital outputs (8):** | |
| Output sink current | 500mA maximum (open collector) |
| Output voltage | 33V maximum |
| Output protection | 33V clamp, all outputs to ground |
| **Analog inputs (10):** | |
| Voltage range | 0 - 5V |
| Input resistance | typically >100M |
| Resolution | 8 bits (20mV/step) |
| Input protection | +/-20mA abs. max input current<br>+/-30mA abs. max total input current |
| **Computer port requirements:** | |
| Centronics type parallel printer port; interface has a 25-pin female 'D' connector, with standard wiring. CMOS or TTL compatible | |
| **Power supply:** | |
| Voltage range | +7.5V to +25V DC |
| Current drain | typically 8-10mA at 9V DC |

## A to D converter

The analog to digital conversion is done entirely by IC4, a TLC542. This device has 11 analog inputs, which are selected one at a time by a 4-bit serial address entered via pin 17. The analog input voltage is converted to an eight-bit number which is then available as serial data from pin 16.

One clock input simultaneously causes the address to be read in and the data to be generated ready for output. The TLC542 has an internal clock which controls the conversion process. The EOC (end of conversion) output generates a low to high transition at pin 19 whenever a conversion is completed.

To convert the analog input voltages to digital values, an external reference voltage is required. The reference voltage inputs are Vref(+) at pin 14 and Vref(-) at pin 13, which in this circuit are connected to Vcc and GND respectively. The relation between the digital output value (N), the reference voltages V- and V+ and the analog input voltage Vin is given by the following formula:

N = integer value of
[255*(Vin - V-)/(V+ - V-)]
= integer value of [51.0*Vin]
when V+ = +5V and V- = 0V

The accuracy of the conversion depends on the actual value of Vcc, which can be anywhere between 4.8V and 5.2V with the nominal 5V regulator used for IC7 (a 78L05). This is a scale error that can be easily removed by the computer program, to get an accuracy typically as good as one LSB (20mV) over the range 0 to +5V.

The analog inputs to the TLC542 are protected by internal clamping against voltages that go outside the range 0 to +5V. These clamps can withstand currents of up to +/-20mA individually, or a total input current for the whole IC of +/-30mA. The external 1k resistors in series with the inputs allows the terminal voltage to reach approximately +25V or -20V before damage occurs.

The interface has 10 inputs for external connections and two dedicated inputs. The eleventh input of IC4, pin 12, is connected via divider network R65/R66 to Vb, the input to the 5V regulator. The voltage divider is arranged so that when

Vb is 25.5V, the voltage at the junction of R65 and R66 is 5V, giving a digital reading of 255. The regulator IC7 requires an input of at least 7V to function properly, so if the digital value read for this input falls below 70, the program can be arranged to give a low voltage warning.

The twelfth input of IC4 is an internal connection to the mid-point between the analog reference voltages, and should always give a digital reading of 128 +/-2, irrespective of the reference voltages. Reading this input is thus an easy way to test a program.

## The power supply

The interface can be operated from any filtered, reasonably stable DC supply with a voltage range between 7.5V and 25V. The supply is connected via series diode D2, which protects the circuit in the event that the supply polarity is reversed. It then passes through transistor switch Q2, which is controlled from the computer via transistor Q1 if J6 is linked between pins 1 and 2. Alternatively if J6 is linked between pins 2 and 3, the interface is switched permanently 'on'.

The output (collector) of Q2 is fed to IC7, a 78L05 voltage regulator, as well as to the supply pin of IC6. Capacitors C14 and C15 provide some filtering to optimise the stability of the 78L05. Diode D1 prevents the output of the 78L05 from becoming more positive than its input under fault conditions, and zener diode ZD2 prevents the +5V rail from being driven to a high voltage in the event that excess voltages are applied to other circuit terminals.

If an unregulated power supply is used, then for best conversion accuracy it is advisable to use a separate power supply for relays or heavy loads that are being controlled by the interface. For example, the interface can be operated from a 9V battery, and relays, solenoids etc., from a plugpack or 12V battery.

## Construction

Assembly of the interface is fairly simple, with all of the components being mounted on a single printed circuit board (PCB) measuring 145 x 68mm. The DB25 connector SK6 which mates with the cable from the computer printer port is fitted at one end.

To place the various components, use as a guide the overlay diagram which shows how the components and wire links (jumpers J1-6) actually fit on the PCB. Read the label of the component, e.g. C1, from the overlay and then look up the description next to that label in the parts list. For example, C1 is an MKT type capacitor and it has the value 0.1uF (100nF); the actual part be marked either '100n' or '0.1'.

Some of the components used are actually a substitute for a wire link. They have the appearance of a 0.25W 5% carbon resistor, but have a nominal 0 ohm resistance, and on the overlay they are shown as a resistor with the label R0. These are used in place of permanent wire links, because they are easier to install than wire links and make the board look more tidy.

Begin construction by mounting the links and resistors R0-70. To find the resistor you want, a table has been provided which shows the colour code for each value.

The last band of the colour code gives the tolerance value and is the one that is farthest from the others. Resistors can be mounted in either direction, but it is good practice to mount them with their colour codes all in the same direction, for ease of reading the values.

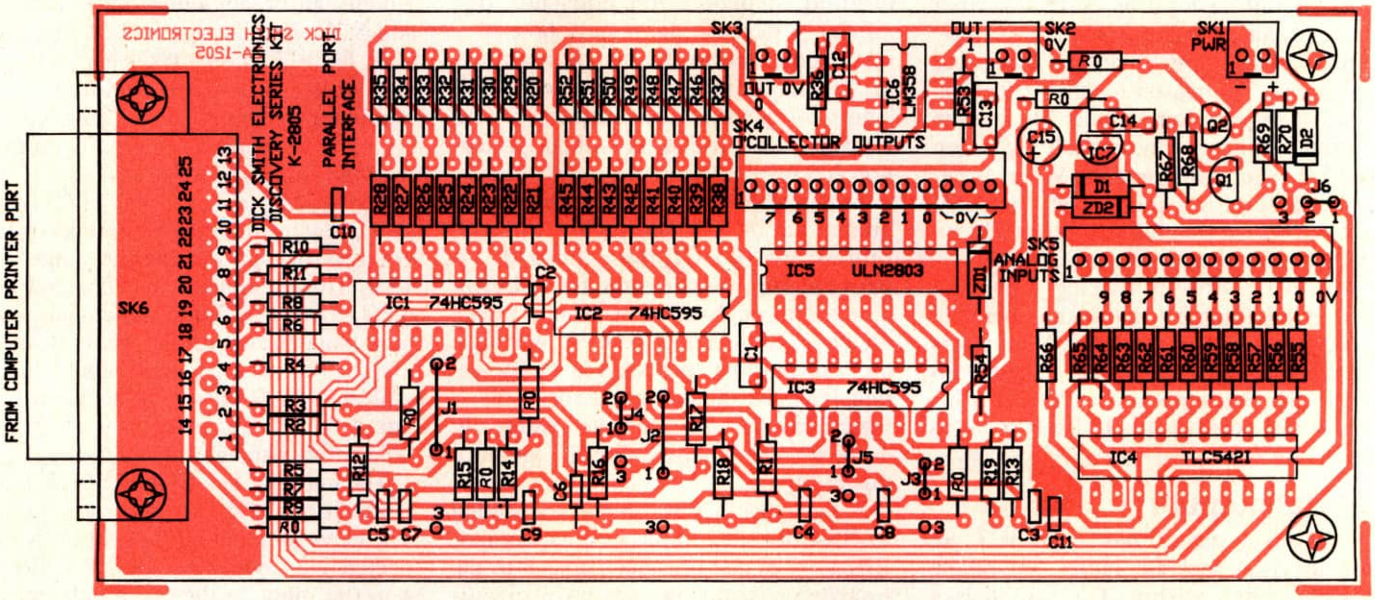
Next mount the diodes D1 and D2 and ZD1/2. These must be mounted in the correct direction only, with the stripe on the very end of the diode corresponding to the striped end on the overlay diagram.

Now mount the capacitors C1-15. One thing to note when identifying a capacitor is that the value can be marked on it in different ways; for example '103', '10n' and '.01' are all the same value and are shortened notations of 10000pF, 10nF and 0.01uF respectively.

Capacitors C1-14 are non-polarised types which can be mounted in either direction, but C15 is a polarised electrolytic which will have a negative (-) or (+) sign marked on it and must be mounted in the direction shown on the overlay.

Next mount the integrated circuits IC1-6. Note that IC's 1-4 are CMOS types, which are sensitive to static electricity. To prevent them from being damaged, note the following precautions:

- Do not remove them from their protective foam until you are ready to install them.
- Avoid touching the pins with your fingers.




*Here is the PCB overlay diagram, showing the location and orientation of all parts used in the interface.*

- Make sure that your soldering iron is properly earthed.
- Solder the power and earth pins of each IC to the board first.

Note that the IC's have a notch at one end, which goes at the end indicated on the overlay diagram.

Next mount the transistors Q1-4. Position them so that in each case the flat side is facing in the direction shown on the overlay. Do not press them down hard onto the board, as this spreads the leads and can damage the transistor's internal connections.

Now mount sockets SK1-6. The pins in the pin header type sockets SK1-5 can be pushed through their plastic casing if too much force is used on them, so before you solder them make sure that the pins are all level.

With the assembly of the board complete, carefully check all the soldering. Look especially for dry solder joints, and solder bridges which may be shorting tracks together.

## Programming control

Finally, a bit more detail on the way the interface can be controlled from your PC program.

The data input to the shift registers which drive the DAC and digital outputs is pin 14 of IC1, which is fed from pin 2 of the printer port (SK6). Looking at Table 1, pin 2 is controlled by bit 0 of the 8-bit byte fed to the port's base address. So we have to send our data to the LSB of the base address, one bit at a time, and follow each bit with a clock pulse at bit 1 of the same address (SK6 pin 3).

For example, to set the voltage at analog output 1 (the second DAC, at SK2) to 1V, the following sequence has to be followed:

1. Convert the voltage to the equivalent digital value of (Vout/20mV) =51 (rounded to nearest integer value).
2. Work out the equivalent 8-bit binary value to be sent to the printer port; here it is 00110011.
3. Send the MSB of this binary value (here 0) to the port base address, by assembling the following data byte and writing it to the port I/O address:
bit 0 = 0 (value MSB)
bit 1 (clock input) = 0
bit 2-6 = 0
bit 7 (power on/off)
= 1 (to turn the power on)
4. Send the same byte as in (3) again, but this time with the clock bit (bit 1) set to 1.
5. Finally send the same byte yet again, but with the clock bit set back to 0, to finish the clock pulse.
6. Repeat steps 3-5 for all the remaining bits of the binary data byte worked out in step 2.
7. Since the above steps will have only sent out the data byte to IC1, another eight clock pulses are required in order to send it to IC2, for the second DAC. Do this by repeating steps 3-5 again, but with either a dummy data byte (all zeroes), or else with the data for DAC1.
8. Finally, load the latch of IC2 by sending the following byte to the base address:
bits 0-2 = 0
bit 3 (load IC2 latch) = 1
bits 4-6 = 0
bit 7 = 1
9. Send the same byte as in (8) again, but with the latch load bit (bit 3) set to 0.
10. Finally, enable the IC2 output gate by sending the following byte to (base address + 2):
bit 0 (IC1 output enable) = 0 (or 1 if DAC1 is to be enabled as well)
bit 1 (IC2 output enable) = 1
bit 2 (not used) = 0
bit 3 (IC3 output enable) = 0 (or 1 if digital outputs are to be enabled as well)
bit 4-7 (not used) = 0

The output of DAC2 should now be 1V, available at SK2.

The equivalent programming for analog to digital conversion will not be described, but the following information should allow you to work out the required steps yourself. As shown in Table 1, the control inputs to IC4 are via the printer port's base address, and its outputs are via (base address + 2).

The normal control sequence needed for analog to digital conversion is as follows:

1. Chip select (CS) of IC4 starts high, and is then brought low to enable the device. The MSB of the last conversion automatically appears on the output.
2. On the first four rising edges of the I/O clock (pin 18), the input address is shifted into IC4, with the MSB first. The negative edges of these clock pulses shift out the second, third, fourth and fifth most significant bits from the last conversion. Sampling of the analog input begins on the fourth falling edge of the I/O clock.
3. Three more I/O clock pulses are applied and the sixth, seventh and eighth bits of the last conversion are shifted out on the falling edges of these pulses.
4. The eighth and final I/O clock pulse is applied. On the falling edge of this pulse, the EOC output goes low and the sampling and conversion continue, for about 32us. The I/O clock input must remain low or the CS (pin 15) taken high, until the conversion is completed. The EOC output goes high to signal the end of the conversion process.
5. Steps 1-4 are repeated to read the result of the conversion.

Using this sequence as a guide, you should be able to work out the programming to achieve it. Remember that the input selection address for IC4 must be sent to it via pin 8 of SK6, corresponding to bit 6 of the printer port base address. As the serial clock line of IC4 is fed from pin 3 of SK6, you'll again need to follow a similar clocking sequence as for the output programming, with a 0-1-0 bit sequence fed to bit 1 of the printer port base address to produce each clock pulse. ❖

### PARTS LIST

**Resistors**

(All 1/4W, 1% unless otherwise stated)

| | |
|---|---|
| R1 | 1M |
| R2-11,55-64 | 1k |
| R12-19 | 10k |
| R20-28,37-45,66,70 | 30k |
| R29-36,46-53 | 15k |
| R54 | 100 ohms |
| R65 | 7.3k |
| R67-69 | 100k |
| R0 | (0 ohm carbon film 1/4W 5% construction) |

**Capacitors**

| | |
|---|---|
| C1,14 | 0.1uF (100nF) MKT |
| C2-11 | 220pF ceramic |
| C12,13 | 1nF (1000pF, 0.001uF) MKT |
| C15 | 10uF 25VW RB electrolytic |

**Semiconductors**

| | |
|---|---|
| D1,2 | 1N4148 small signal diode |
| ZD1 | 1N4752 33V/1W zener |
| ZD2 | 1N4735 6.2V/1W zener |
| Q1 | BC549 NPN small signal transistor |
| Q2 | BC559 PNP small signal transistor |
| IC1-3 | 74HC595 shift register |
| IC4 | TLC542I serial ADC |
| IC5 | ULN2803 octal Darlington driver |
| IC6 | LM358N dual op-amp |
| IC7 | 78L05Z 5V regulator |

**Miscellaneous**

| | |
|---|---|
| SK1-3 | Two-way SIL pin header and plug |
| SK4,5 | 12 way SIL pin header and plug |
| SK6 | 25 pin, PCB mount 'D' socket |
| PCB | 147 x 71mm, coded ZA-1205; |

216-type 9V battery snap; two 9mm long M3 bolts with washers and nuts.

### Resistor Colour Codes

| Value | 4 Band 1% | 5 Band 1% |
|---|---|---|
| 100 | Brn Blk Brn | Brn Brn Blk Blk Blk Brn |
| 1k | Brn Blk Red | Brn Brn Blk Blk Brn Brn |
| 7.3k | Vio Org Red | Brn Vio Org Blk Brn Brn |
| 10k | Brn | Blk Org Brn Brn Blk |
| 15k | Brn | Grn Org Brn Brn Grn |
| 30k | Org Blk Org | Brn Org Blk Blk Red Brn |
| 100k | Brn Blk Yel | Brn Brn Blk Blk Org Brn |
| 1M | Brn Blk Grn Brn | Brn Blk Blk Yel Brn |