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Constructional Project

MULTI-CHANNEL TRANSMISSION SYSTEM   by ANDY FLIND

A PIC-based 8 to 16-Channel 2-wire on-off signaling communication link. An add-on Interface (next month) will extend possible options to internal private telephone and intercom systems.

This project provides up to sixteen channels of on-off signaling communication through just a single pair of wires, in one direction or in both directions simultaneously. In a one-way system the Transmitter may be powered through the same pair of wires, which allows the monitoring of up to sixteen inputs from locations having no local power supplies. An interfacing option (next month) enables operation through audio circuits, such as private internal telephone and intercom systems.

Although ideal for remote signaling and alarm system monitoring, other possible applications could include such things as environmental monitoring, model railway controls and switching for advanced lighting or display systems. The versatility of using circuit modules, and the ways in which they can be connected together, means that possible applications are limited only by the constructor's own imagination.

HOSPITAL CALL

Like many designs, this one began with a request from a friend, who on this occasion is the volunteer engineer for the local "Hospital Radio". Although operated by amateurs, this service manages to maintain impressively high operating standards.

At present a new studio is being constructed at some distance from their existing one and for a while they will be operating these simultaneously, often with a disk jockey. working in both. To make this possible, a number of signaling channels are required for functions such as indicating when a

microphone is in use. Security monitoring channels are also needed since the original studio is housed in a "Portacabin" and has suffered from attempted break-ins.

The request, then, was for the provision of sixteen "on-off" signaling channels to operate through a single circuit from the hospital's internal telephone system. Plus, the icing on the
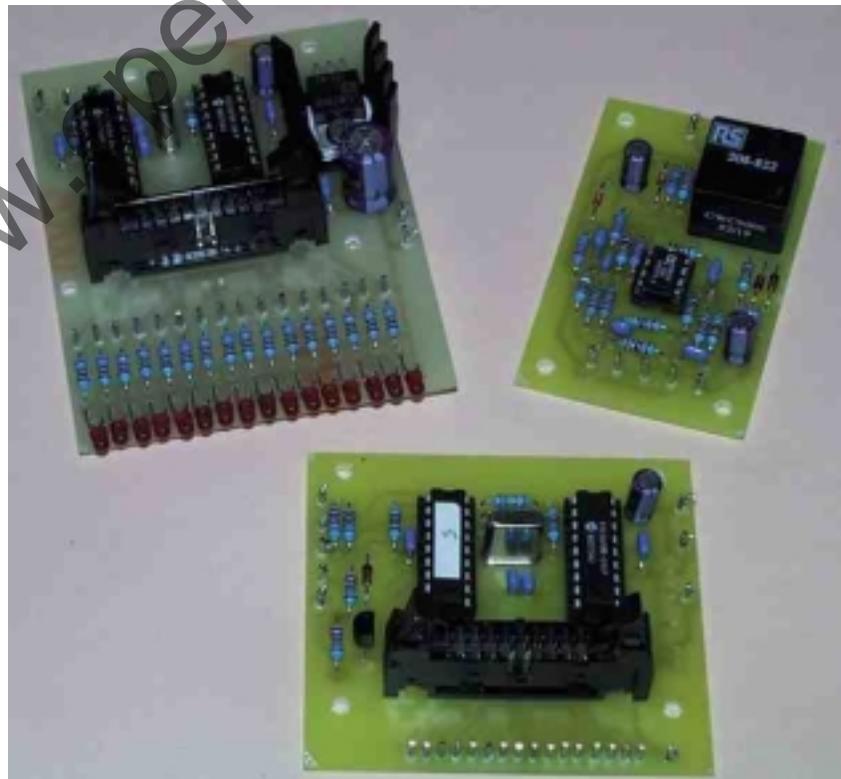
The three modules: Receiver board; Interface (next month) and, foreground, Transmitter board.
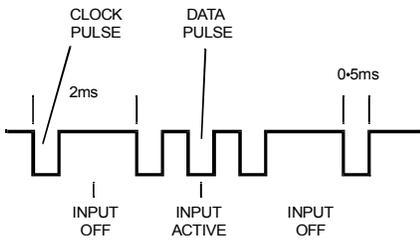
Fig.1. Transmission method
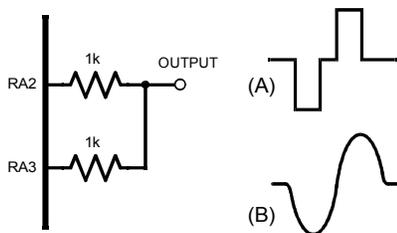
Fig.2. Waveform generation.

designer's cake, it was required to operate simultaneously in both directions.

TAKE YOUR PIC

Initial thoughts were that the task could be carried out easily with a suitably programmed PIC. Whilst the programming proved far from easy, it eventually resulted in the extremely versatile system described here.

It can operate to the original specification with sixteen channels in each direction through a circuit capable only of handling low-level audio signals, but, as described, it can also be used in several other ways to suit less demanding applications. It can have either eight or sixteen channels, in one or both directions, and in some cases the Transmitter may be powered through the signaling wires which can sometimes be very useful.

Later upgrading of a system is also simple, as the second eight channels can be added by simply plugging in extra PICs. This is a project offering lots of possible options for tailoring the configuration to suit the

individual constructor's needs.

SENDING A SIGNAL

The method of signal transmission used is relatively simple. A total of sixteen "clock" pulses are sent and for each there is a following "signal" pulse if the associated input is active. Part of the resulting waveform is shown in Fig.1.

It can be seen that the pulses are negative-going, with a positive quiescent state which allows the signaling line to serve as the transmitter power supply if required. The basic timing of each pulse is 0·5ms low, 0·5ms high, so that if all the switches are active the sequence becomes a burst of 1kHz tone, a suitable frequency for transmission through an audio circuit.

Squarewaves with a peak-to-peak amplitude of 5V are not suitable for telephone circuits however, as stray coupling into adjacent circuits in the cables is likely to cause interference to other users. The original intention was to "smooth" and attenuate the waveform with passive low-pass filtering and restore it at the far end with a comparator, but this idea failed since telephone circuits usually carry only AC signals due to coupling transformers and capacitors.

The average DC content of the waveform produced by this project varies with the number of active inputs and the resulting variation of the average level at the far end of an AC coupled circuit made it impossible to adjust the comparator for reliable operation. A solution was eventually found for this problem, the principle of which is shown in Fig.2.

Two outputs from the PIC (RA2 and RA3) are connected
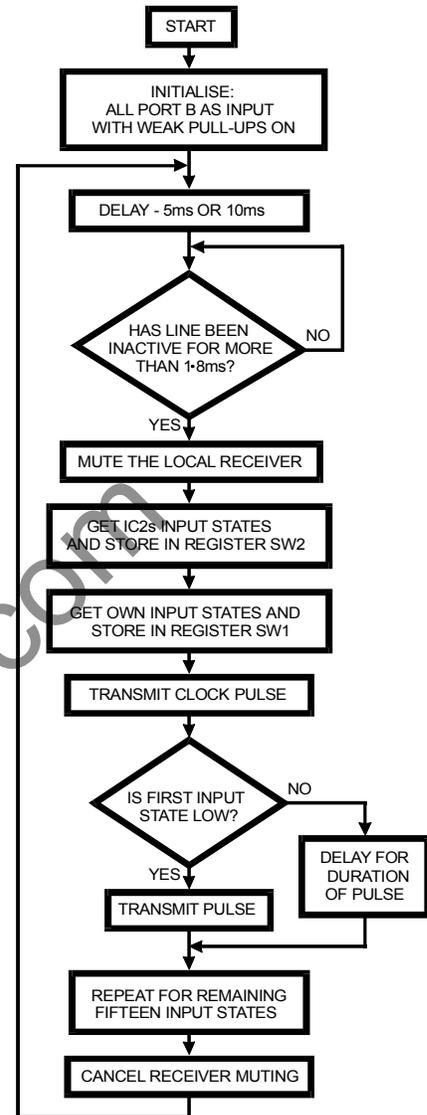
Fig.3. Flow diagram for the first Transmitter PIC, IC1.

through a pair of 1 kilohm (1k) resistors and the output is taken from their junction. The quiescent state consists of one output high (positive) and one low (negative) so that the output is half the supply voltage. A "signal pulse" consists of making both outputs low, followed by a return to the quiescent state, then both outputs high, then back to one high, one low.

This results in the waveform shown at Fig.2a, which is much better for transmission through an

```
                    START

              INITIALISE:
           PORT A BIT 2 INPUT
         ALL PORT B AS INPUT
        WITH WEAK PULL-UPS ON

              IS PORT A          NO
              BIT 2 LOW?
                 YES

          GET PORT B STATES
           STORE IN FILE SW1

              IS PORT A          NO
             BIT 2 HIGH?
                 YES

        MAKE PORT A BIT 2 OUTPUT

         SET PORT A BIT 2 HIGH

             IS FIRST BIT        NO
             OF SW1 LOW?
                 YES

          SET PORT A BIT 2 LOW

          DELAY FOR 100ms

        REPEAT FOR REMAINING
         SEVEN BITS OF SW1

       MAKE PORT A BIT 2 AN INPUT
```
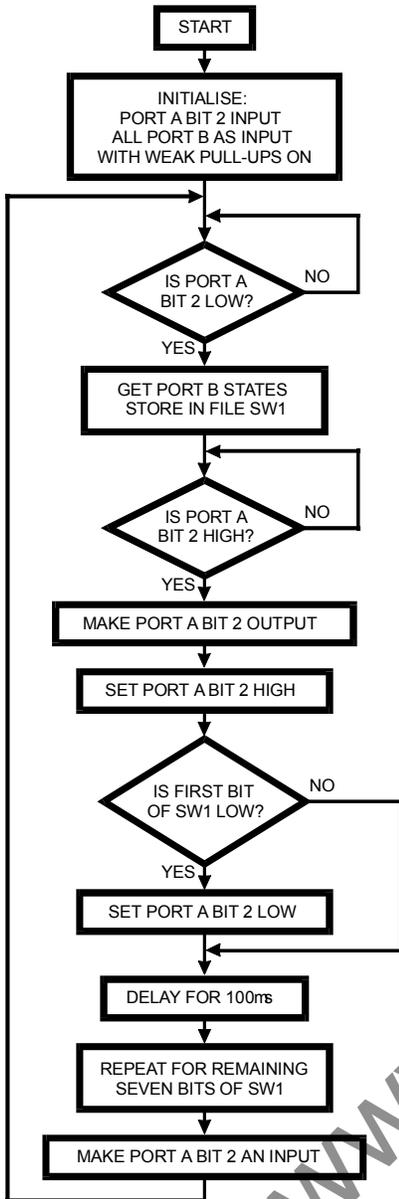
Fig.4. Flow diagram for the second Transmitter PIC, IC2.

AC circuit. Furthermore, if the "low" and "high" states occupy around 61 per cent of the total period the energy content will be similar to that of a cycle of sinewave. When passed through a suitable low-pass filter this produces a very good approximation of a sinewave as shown in Fig.2b, far more suited to telephone circuits.

In passing, it's worth mentioning that with a 5V supply the current "wasted" by the two resistors in the quiescent state is only 2·5mA as they present a series resistance of 2 kilohms, whilst the output impedance is only 500 ohms as for this they are effectively in parallel.

BI-DIRECTIONAL OPERATION

Achieving bi-directional operation was more difficult. In telephony there are "two-to-four-wire" converter circuits which split the conventional two wires into separate transmit and receive pairs. They work by coupling the circuit to the receiver through an impedance of some kind, often just a resistor, and injecting an inverted form of the locally transmitted signal into the receiver to cancel the bit of it that comes through this impedance.

Success with this type of circuit assumes that the transmission path will have a known and constant impedance, both resistive and reactive, and attempts to use it with the proposed telephone circuit failed miserably. Eventually a software solution was found in which each transmitter checks the line for silence before transmitting and mutes the local receiver before doing so. Two such transmitters can be made to synchronize to each other and take turns to transmit.

The PIC16F84 can have internal "weak pull-up" resistors applied to the eight bits of port B when these are configured as inputs, removing the necessity to provide them externally. Each input can then be as simple as just a switch pulling it to ground if required.

A single PIC can only provide eight such inputs however, and this project required sixteen. Since these ICs are now available at a cost of less than 2 UK pounds from some suppliers, the quickest and cheapest way to obtain a further eight inputs is from a second PIC which transmits its inputs serially to the first upon request.

SOFTWARE OPERATION

An outline of the software operation for the first PIC, IC1, in the Transmitter circuit is shown in the flow diagram Fig.3. The initial setting up includes configuring all of port B as inputs with active weak pull-ups.

This is followed by a brief delay. It is unlikely but quite possible that both transmitters in a bi-directional system might check the line, find it inactive and transmit together in perfect synchronization. The use of a slightly different delay in each transmitter will quickly break such a pattern to ensure correct operation. Five and ten milliseconds are the values used for this.

Following the delay the PIC monitors the line for a period of inactivity greater than 1·8ms, after which it mutes the input to the local receiver, collects the input states from the second PIC, IC2, and stores them in a register named SW2, and then stores its own input states in register SW1. It then transmits the first clock "pulse" as described earlier and checks the first bit of SW1. If this is clear, corresponding to an active input, a second pulse is transmitted. If it is set, the input was inactive so a delay lasting the period of a pulse is called.

This action is repeated for the remaining seven bits of SW1 followed by the eight bits of SW2, the whole process taking precisely 32ms. After this the program returns to the start and the entire sequence is repeated.
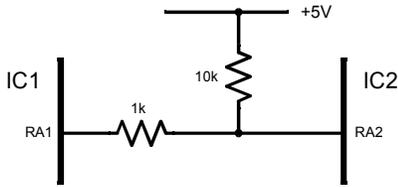
Fig.5. Communication between two PICs

A flow diagram of the Transmitter software for IC2 is shown in Fig.4.

PIC-TO-PIC

From time to time readers have asked how communication between PICs can be achieved so a detailed description of the method used may be helpful. In this circuit two PIC connections (RA1 and RA2) are linked as shown in Fig.5. A 1k resistor is used in case both pins become outputs simultaneously, although this should never be the case.

Initially, both connections are configured as inputs and the 10k resistor pulls them both high. When IC1 requires data from IC2, it's pin becomes an output and is pulsed low for about 400us before returning to the input state.

Meanwhile, IC2 has been waiting for the low pulse. On seeing this it stores its input states in a register and waits for the input to return to the high state. When this happens it makes its pin an output and sends the eight input states serially at intervals of 100us. Following this the pin returns to the input state and the program returns to the start to wait for the next pulse from IC1.

In the meantime, 50us after restoring its connection to input, IC1 commences taking eight readings from it at 100us intervals and storing the results in register SW2. The whole
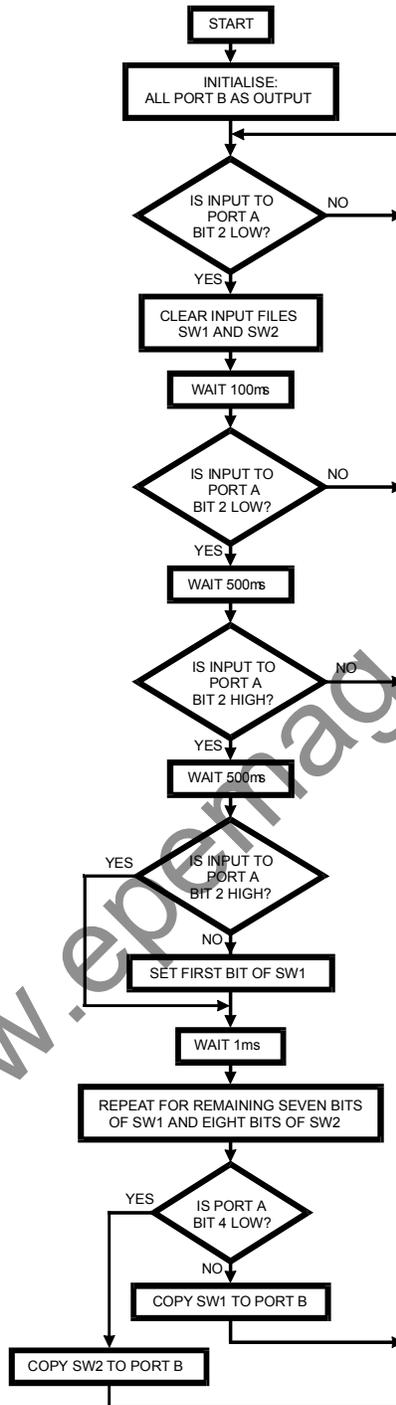

Fig.6. Flow diagram for the Receiver.

process takes just over a millisecond and is easy to implement, both in hardware and software. This is serial communication at its simplest

and more sophisticated methods are obviously possible but it provides a starting point for anyone wanting to connect two or more PICs together.

One advantage of this method is that for eight-channel operation IC2 can be omitted. IC1 will still request the information but will "see" eight inactive inputs as each time it reads the pin it will see a high state set by the 10k resistor.

RECEIVER SOFTWARE

Continuing with the Receiver, the flow diagram for this is shown in Fig.6. The program begins by looking for a falling edge in the input signal from the line. When it locates one it clears the two input registers named SW1 and SW2 which will contain the sixteen switch states.

It then waits for 100us, which should take it into the low portion of a pulse if this was the origin of the edge. It checks the input is still low, if not it returns to the program start. Otherwise, it waits for 500us and checks that the input is now high, as it will be if a pulse is present. Again, if it isn't the program returns to the start.

After another 500us, which takes it to the point where the input will be low or high depending on the input state being transmitted, it samples the state of the line and stores it in the first bit of register SW1. A further delay of 1ms takes it to the next clock pulse, where the process is repeated until all sixteen pulses have been checked and their associated data bits read.

Both low and high states of all sixteen clock pulses are checked and if any are missing
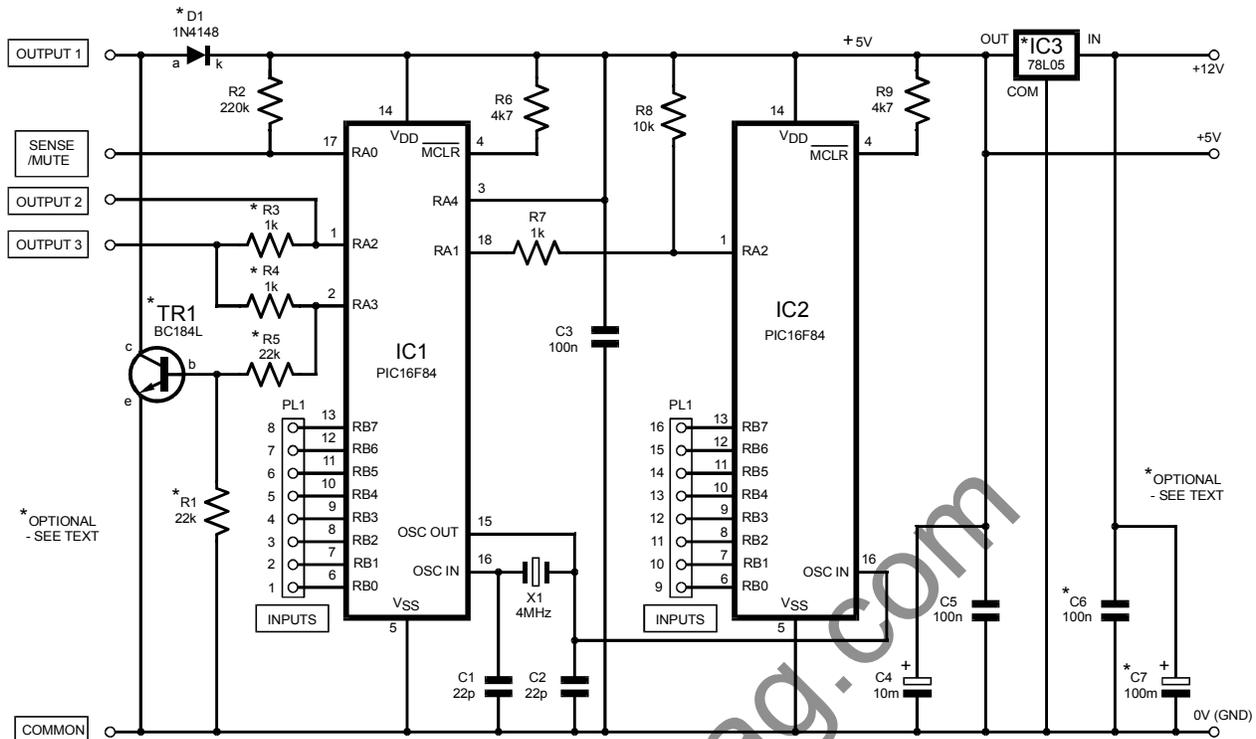
Fig.7. Full circuit diagram for the Transmitter section. Note the items marked with an asterisk are optional – see text.

the program immediately returns to the start. This provides rapid synchronization to the transmitter and good protection against data corruption as a complete valid sequence must be received before output takes place.

Assuming a complete sequence is received, the program now checks the input to port A bit 4. This is wired "high" for IC1 and "low" for IC2, so the PIC knows which socket it is in and sends the appropriate eight bits of data to port B, SW1 in the case of IC1 and SW2 for IC2.
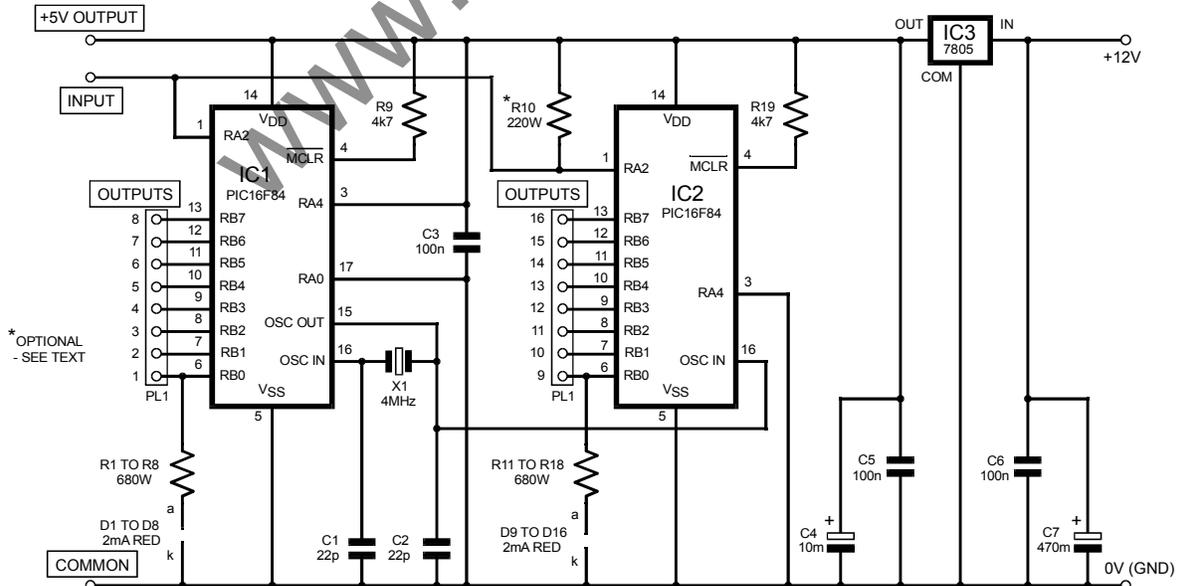
Fig.8. Complete circuit diagram for the Receiver section of the Multi-Channel Transmission System.

Complete Receiver module, including the LEDs. The LEDs, together with their associated resistors, can be omitted if you wish – see text.
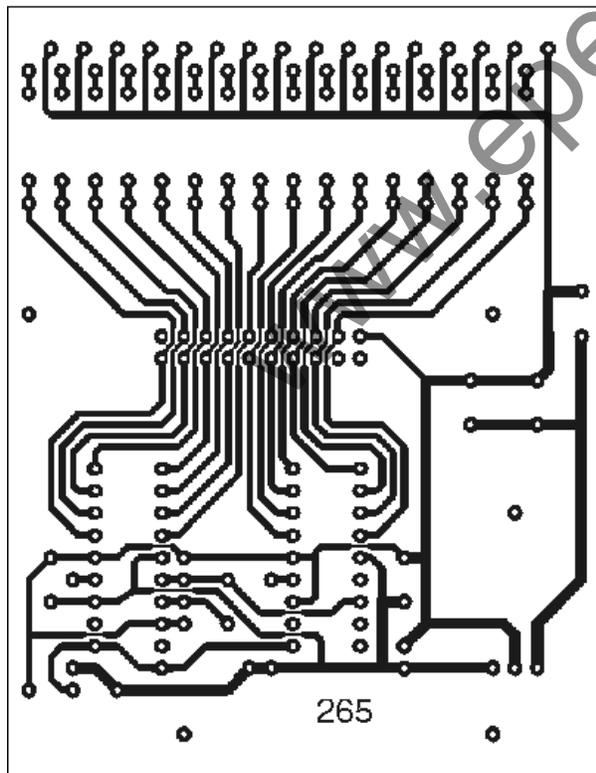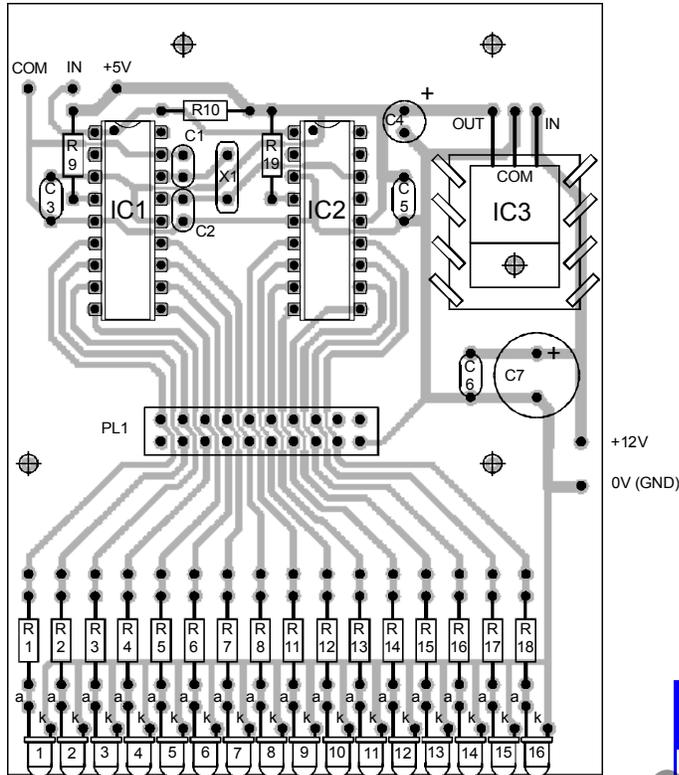
Fig.9. Receiver printed circuit board component layout and (approximately) full-size copper foil master pattern.

COMPONENTS

RECEIVER

Resistors

R1 to R8, R11 to R18	680 ohms (16 off)
R9, R19	4k7 (2 off)
*R10	220 ohms

All 0.6W 1% metal film

Capacitors

C1, C2	22p resin-dipped ceramic (2 off)
C3, C5, C6	100n resin-dipped ceramic (3 off)
C4	10u radial electrolytic, 63V
C7	470u radial electrolytic, 25V

Semiconductors

D1 to D16	red LEDs, 2mA type (16 off)
IC1, IC2	PIC16F84 pre-programmed microcontroller (2 off)
IC3	7805 5V 1A voltage regulator

Miscellaneous

X1	4MHz crystal
PL1	20-way IDC header plug

Printed circuit board available from the *EPE Online Store*, code 7000265 (Receiver) at **www.epemag.com**; 18-pin DIL socket (2 off); small heatsink for IC3; multistrand connecting wire; solder pins, solder, etc.
Note: Resistor R10 is optional (see text).

See also the SHOP TALK Page!

Approx. Cost Guidance Only   **$32**

COMPONENTS

TRANSMITTER

Resistors
*R1, R5 22k (2 off)
R2 220k
*R3, *R4, R7 1k (3 off)
R6, R9 4k7 (2 off)
R8 10k
All 0.6W 1% metal film

Capacitors
C1, C2 22p resin-dipped
ceramic (2 off)
C3, C5, *C6 100n resin-dipped
ceramic (3 off)
C4 10u radial electrolytic, 63V
*C7 100u radial electrolytic, 25V

Semiconductors
*D1 1N4148 signal diode
*TR1 BC184L *npn* transistor
IC1, IC2 PIC16F84 pre-prog-
rammed microcontroller (2 off)
IC3 78L05 5V 100mA voltage
regulator

Miscellaneous
X1 4MHz crystal
PL1 20-way IDC header plug

PCB available from the *EPE Online Store*, code 7000264 (Transmitter)
www.epemag.com; 18-pin DIL socket (2 off); solder pins, solder, multistrand connecting wire, etc.
Note, All components marked with an asterisk are optional (see text).

See also the SHOP TALK Page!

Approx. Cost Guidance Only **$26**

Fig.10. Printed circuit board topside component layout and (approximately) full-size under-side copper foil master pattern for the Transmitter.

In contrast to the Transmitter there is no communication between the two ICs which both simply check and store all sixteen bits and output the appropriate set. This allows them to use identical software and, as with the Transmitter, if just eight channels are required the second IC can be simply omitted.

An examination of the software of this project will reveal that it is written in straightforward "top-down" style with most repetitive operations simply repeated the appropriate number of times in preference to using loop techniques. This tends to improve reliability and is easy to follow, even though it is more tedious to write.

TRANSMITTER CIRCUIT

As with many PIC projects, the circuits are relatively simple as so much of the work is done by the software. The only complexity is in the Transmitter where the various methods of use make some of the components optional.

These options will be explained in more detail next month. For now the simplest method will be described so that construction and testing can be carried out.

The full circuit diagram of the Transmitter is shown in Fig.7. The two 16F84 PICs, IC1 and IC2, share a common clock using the oscillator of IC1 with a
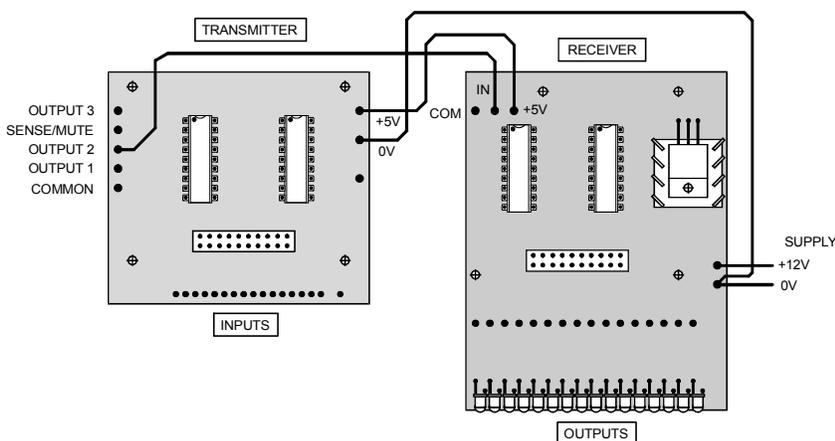
Fig.11. Test set-up for checking out the two PCBs.

4MHz crystal X1 and capacitors C1 and C2.

Both IC1 and IC2 have all eight inputs of port B pulled high internally so these are simply brought out to pins to which external connections can be made. The communication between them is through resistor R7 with pull-up resistor R8. A digital output is taken from IC1 port A bit 2 (at pin 1), which is normally high and goes low for clock and data pulses.

The sensing and muting function, only required for synchronized bi-directional use, is performed with port A bit 1 (at pin 18) and operates as follows. When used in this way the signal is coupled to the local receiver through a 10k resistor, and the sense/mute pin is also connected to the receiver side of this resistor.

Initially it is an input, and listens for a continuous "high" signal to confirm that the other transmitter is not sending. Once this is detected it is converted to an output and set high for the duration of transmission, so the local receiver effectively sees a continuous inactive line. Where this facility is not required, resistor R2 holds this pin high so that transmission will take place anyway.

Other optional bits are resistors R3 and R4 which are only required if the unit is used with the Interface circuit to be described next month, and resistors R1, R5, transistor TR1 and diode D1, are needed if it is to be powered through a 2-wire connection from the distant Receiver. The principle here is that one of the two wires is a common ground (0V), or negative, whilst the other is energized from +5V through a 220 ohm resistor (an option in the Receiver) and charges capacitor C4 via diode D1 whilst the line is high. Then C4 supplies the circuit whilst the line is pulled low for pulses by transistor TR1.

Finally, there is an optional on-board 5V supply regulator, IC3. In most cases the Transmitter will be supplied with +5V from a Receiver, either local for a bi-directional system or remote. However, if an application requires that it should be self-powered for any reason, regulator IC3 can be fitted together with input decoupling capacitors C6 and C7. In most cases these three components will not be needed. Also, of course, where only eight channels are needed IC2 may be omitted.

RECEIVER CIRCUIT

The Receiver circuit diagram shown in Fig.8 is even simpler. As with the Transmitter, the two PIC16F84s, IC1 and IC2, share a common 4MHz crystal clock. However, there is no communication between them. Instead the input signal is connected to RA2 (at pin 1) of both PICs. Each of the sixteen outputs is provided with a resistor supplying a LED (light-emitting diode). These can be omitted if not required although they are useful when testing. For clarity only one resistor and one LED are shown for each IC in Fig.8, since the others are identical. The supply regulator IC3 is a robust 1A type mounted on a small heatsink as is has to supply the LEDs and probably also some output circuits and a Transmitter. The only optional component is resistor R10 which is needed if 2-wire operation with the Transmitter powered from the line is intended.

CONSTRUCTION

Construction of this project is straightforward. The Transmitter and Receiver circuits, that make up the Multi-channel Transmission System, are both built up on single-sided printed circuit boards (PCBs). These boards are available from the *EPE Online Store* (codes 7000264 (Transmitter) and 7000265 (Receiver)). The Interface PCB (next month) is also available (code 7000266), all from the *EPE Online Store* at **www.epemag.com**

Starting with the Receiver, all the components except resistor R10, just above IC1, should be fitted as shown in Fig.9. The use of DIL sockets is recommended for the two PICs, IC1 and IC2.

Solder pins are suggested for the external connections, as these will then be more robust and can be made from the component side of the board. A degree of force is sometimes required to insert such pins so it may be best to fit them first.

The LEDs, which should be 2mA types, and their associated resistors are optional. Where fitted it is not too difficult to bend their leads in the required manner, and a little "Blu-Tack" or "Play-Do" may be helpful for holding them in position during soldering.

Not mentioned so far is the plug PL1. A requirement for the original application was a means of rapid connection and removal for testing and service purposes so 20-way IDC header plugs were included in the design. These are retained in this project but can be omitted if not required.

The two PICs should not be inserted yet. An initial test is to supply the completed Receiver board with +9V to +12V which should result in a supply current of about 4·8mA whilst the regulated output of +5V should be available from the solder pin, marked +5V, just above IC1.

TRANSMITTER

If the above test is satisfactory construction can continue with the Transmitter PCB, the component layout, together with an approximately full-size copper foil master, is shown in Fig.10. All the optional components should be omitted at this stage and the two PICs should not be inserted.

Once the board has been completed, it is worth checking initially by powering it with a 5V supply taken from the Receiver. It should draw virtually no current at all since the only components bridging the supply are the three decoupling capacitors. However, short circuits do occasionally occur in construction and electrolytic capacitors have been known to be fitted the wrong way round!

TESTING

If all seems well IC1, programmed with TXIC1_5 (5ms delay) or TXIC1_10 (10ms delay) software, can be inserted. This should raise the supply current to about 2mA and the average voltage measured with a meter at Output 2 should be about 4V, indicating that IC1 is operating and transmitting an appropriate pulse sequence.

Next, a PIC programmed with receiver RX software should be inserted into the Receiver board at IC1 position and a connection made from Output 2 of the Transmitter to "IN" of the Receiver as shown in Fig.11. Connecting any of the first eight inputs (1 to 8) to ground (0V) should now illuminate the corresponding output LEDs on the Receiver or take the appropriate outputs high if the LEDs are not fitted.

Finally, if all sixteen channels are required, a second PIC with RX software can be fitted to the Receiver and one with TXIC2 software to the transmitter, after which the remaining eight channels (9 to 16) can be tested. The two boards are now operational and ready for use.

RESOURCES

Software for the *Multi-Channel Transmission System Transmitter* and *Receiver* modules is available for free download from the *EPE Online Library* at **www.epemag.com**

Ready-programmed PICs are also available and full details, including the above options, can be found in the **Shoptalk** page in this issue.

Next Month: Details of the various ways in which these units can be used will be given, together with the construction of an Interface board for use with internal telephone circuits or similar long lines. This is effective in reducing or eliminating the radiated interference sometimes caused by high-level digital signals in transmission circuits.