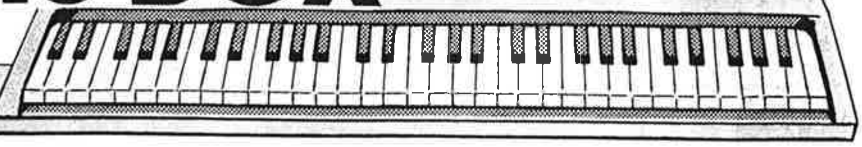
MYSTERIES OF MIDI & MIDI THRU BOX



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An explanation of the use of the Musical Instrument Digital Interface and a simple project

ADVANCES in modern technology enable a single musician to play several instruments simultaneously, or a group of musicians to perform together with precision timing, an essential element in the enjoyment of playing or listening to music. These functions became possible because of the development of the sequencer and the MIDI interface. The sequencer is a microprocessor controlled module which is similar in use to the multi-track recorder, but which stores information regarding pitch, timbre, amplitude, timing and control signals in digital form. This data, when transferred to a digital, polyphonic synthesizer, causes the synthesizer to play automatically, together with any other digital keyboards and drum machines linked by MIDI interface.

All modern digital electronic instruments are microprocessor controlled and the MIDI interface ensures that the processor clocks are synchronised in order that they will all perform functions at the precise times. The term MIDI is derived from the initials of Musical Instrument Digital Interface and is an internationally agreed standard of communication between microprocessor systems used in music applications. It enables the chaining of two or more instruments, equipped with the interface, by means of a single cable between each. The interface was designed and developed through the co-operation of major musical instrument manufacturers to overcome the problem of linking together instruments produced by different companies.

MIDI laid down rules by which digitised musical information could be transmitted and received in a standard form. Both the software and hardware specifications are formally documented and have been accepted by most leading electronic musical instrument manufacturers since its development in 1982. While MIDI Implementation Charts and transmit/receive data bit patterns are supplied with instruments, unfortunately, instruction manuals supplied with the instruments offer very little useful information about the operation of MIDI and some instructions deviate from the standard. It is hoped here to put some clear meaning into the standard instruction set, to help non-technical reader/instrumentalists get a little more out of their instruments.

MIDI is a bi-directional asynchronous serial interface similar to the familiar RS232 serial interface, but with a much higher baud rate of 31·250, which is arrived at by subdividing 1MHz. Unlike the RS232, which has signal voltage levels of +3V to +12V and −3V to −12V, the MIDI interface only requires 0V to 5V logic signal levels. The inputs are opto-isolated to ensure the absence of earth loops which prove so troublesome with many items of audio equipment. Connections are via standard five pin, 180 deg. DIN sockets and provision is made for MIDI-IN, MIDI-OUT and with some instruments, MIDI-THRU, this being a buffered direct copy of the MIDI IN signal; Fig. 1.

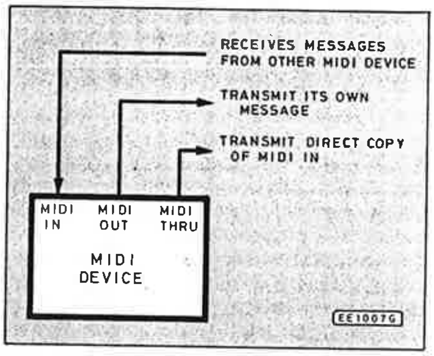


Fig. 1. MIDI THRU is a copy of MIDI IN.

FORMAT

The format of the MIDI interface was chosen as a compromise between speed and low cost. The transmission speed is high enough for all but the most sophisticated applications and is cheap enough to be included in even the least expensive units. Although information is in serial form, the microprocessor speed is sufficient to give the impression that sound is instantaneous. The microprocessor in each machine is able, through a specialised software language, to translate the digital coding received from the Master source, digital data being identical whether transmitted, or received.

The Master unit can be any unit in a group that can include keyboards, synthesizers, drum machines, sequencers and computers. Normally the choice depends on whether pre-programmed music is being played, or whether one or more keyboards are being played in real time, with backing from other instruments or sequencers. Ultimately the choice will always fall on the instrument which offers the simplest instruction set, or the most suitable unit for a specific application. As an example, the author uses a sequencer as Master when tracks have been programmed into it. The eight-track sequencer then controls the start and stop of a programmable keyboard, and programmable drum machine, together with the timbre, pitch, time values and effects on eight independent tracks of a synthesizer. In addition to this, the keyboard and synthesizer can be split and played in real time if required. As an alternative, the author, when playing in real time, uses the keyboard as Master, with MIDI controlled, pre-programmed rhythms stored in the drum machine and MIDI selected tones from the synthesizer that play simultaneously with the Master keyboard. As the author's machines have no MIDI THRU facilities a MIDI THRU box has been designed and is described later in this article.

EXAMPLES

To illustrate the examples above, in the first instant the MIDI OUT of the sequencer is plugged into the Master or IN socket of the MIDI THRU box. The outputs from the box are then connected to the MIDI IN sockets of the synthesizer, keyboard and drum machine with standard five pin DIN leads and in any order, Fig. 2.

In the second example the MIDI OUT of the keyboard is plugged into the Master socket of the MIDI THRU box and two of the outputs connected to the synthesizer and drum machine, Fig, 3.

In the situation shown in Fig. 4 synthesizers A and C have MIDI THRU sockets which make the following functions possible. If A is played, the performance data of A will be sent through its MIDI OUT to B, which will sound. C will not sound as it is connected to the MIDI OUT of B. This is because the data fed into the MIDI IN of B is not outputted through the MIDI OUT. Therefore when A is played only A and B will sound.

If B is played, B's data will be sent from its MIDI OUT to the MIDI IN of C, making C sound. At the same time, a direct copy of the signal will be sent from C's MIDI THRU socket to the MIDI IN of A causing A to sound. Therefore playing B causes A, B and C to sound. In theory many MIDI

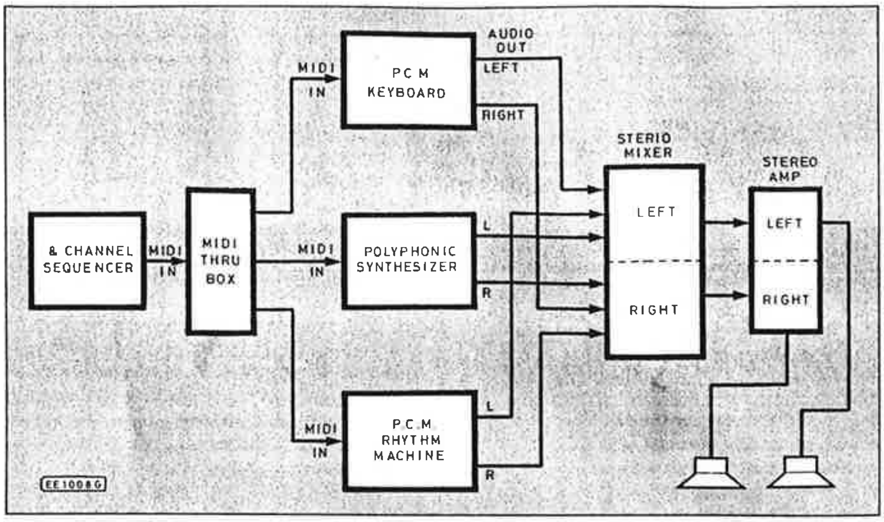


Fig. 2. Example of connections using MIDI THRU.

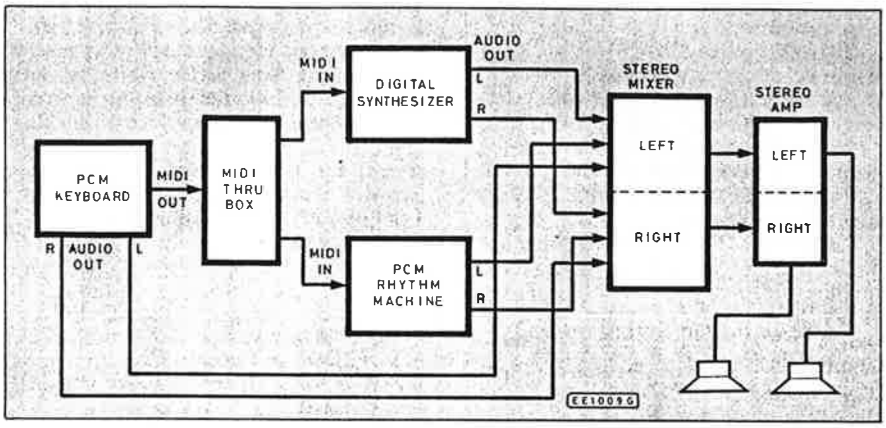


Fig. 3. Keyboard driving synthesizer and rhythm machine.

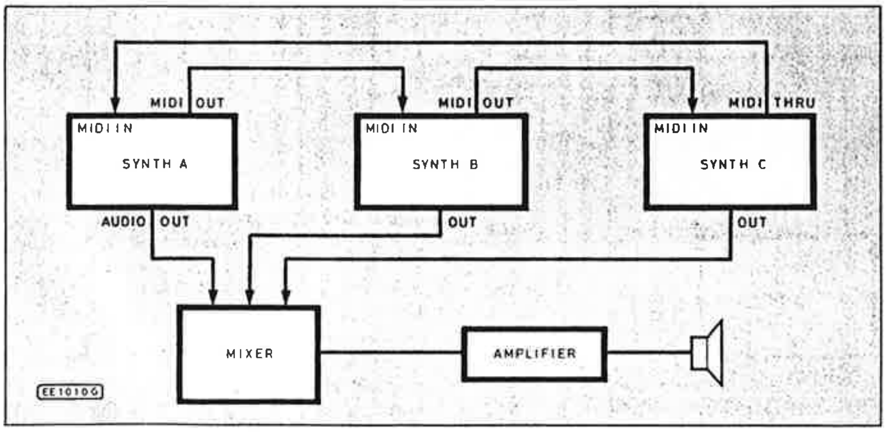


Fig. 4. Synth A, B and C will sound if B is played.

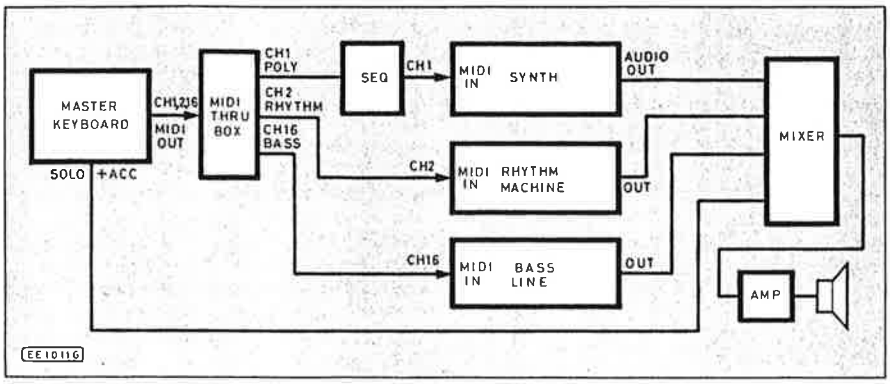


Fig. 5. An example of channelising.

devices can be connected by using MIDI THRU's, but as these are buffered outputs there will be a time when delays are noticeable. This makes the MIDI THRU box the more efficient method of distribution, or channelising as this is known.

Some machines that do not have MIDI THRU sockets send the data fed to it at its MIDI IN direct to its MIDI OUT socket, while others have a single socket with selectable MIDI OUT, MIDI THRU. Yet again some have only a single MIDI IN socket because the others are considered unnecessary.

As modern instruments produce a stereo output these effects should be maintained by using a mixer with left and right input channels.

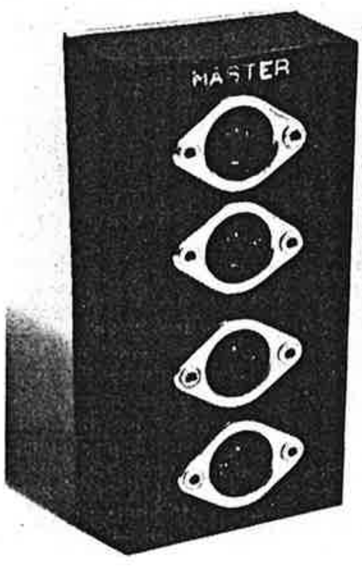
CHANNELISING

A single MIDI cable can be used to transmit several messages to different instruments at the same time through one of the sixteen channels, Fig. 5. Each message, carrying information of pitch, tone, modulation etc. is sent on a different channel and the receiving instruments are tuned in to the channels carrying the information you wish them to respond to. Although every instrument has 16 channels at its disposal, the number of channels that can be used at any time depends on the number of functions the instrument and its associated modules are each capable of. For instance, an instrument that is limited to rhythm, bass, accompaniment, poly and solo can utilise five different channels to transmit data to modules assigned to receive the messages.

The set-up illustrated below left shows a typical method of distribution. Any channel number can be chosen for each function, providing the receiving module is capable of "tuning in" to a particular channel. Some modules are only equipped with a single channel and have to be allocated that channel exclusively. In the example it is assumed that the Bass Line is only capable of receiving on Channel 16.

The concept of channelising is similar to that when television stations broadcast by transmitting wireless signals (each comprised of sound, vision, teletext, synchronisation signals etc.) through different channels respectively. A TV set receives all the information from one antenna, but can select any desired broadcast by switching the channel selector.

The chart lists the codes of Channel and System messages. The first byte of Channel messages have a note triggering code and channel number.



TRANSMITTED and RECOGNISED DATA

STATUS 1st Byte	DATA 2nd Byte	 3rd Byte	Description	
1000nnnn	0kkkkkkk	0vvvvvvv	Note Off	Receive only function n = channel number 0–15 (Channels 1–16) k = key value 0–127 (limited by keyboard) v = note velocity 0–127 (key off velocity) ignored
1001nnnn	0kkkkkkk	0vvvvvvv	Note On/Off	n = channel number 0–15 k = key 0–127 v = note velocity 0–127 (0 = Note Off 64 = Note On)
1011nnnn	0ccccccc	0vvvvvvv	Control Change and Mode Messages	n = channel number 0–15 c = control number 0–127 c = 1 modulation wheel c = 5 Portamento time c = 6 master time c = 64 sustain c = 65 portamento off c = 92 tremolo c = 93 chorus c = 94 celeste c = 123 all notes Off v=0 c = 124 OMNI Mode Off v=0 c = 125 Omni Mode On v=0 c = 126 Mono Mode On v=0 c = 127 Poly Mode On v=0 (123–127 All Notes Off) v = note volume 0–127 (0 = Note Off 127 = Note On)
1100nnnn	0ppppppp		Program Change	n = channel number 0–15 p = program 0–127 (tone or rhythm pattern storage —typically 32 ROM, 32 RAM)
11110011	0sssssss		Song Select	s = song 0–127 (song or rhythm sequence typically 8 ROM 8 RAM)
11111000			Clock	Transmitted when internal clock is selected
11111010			Start	
11111100			Stop	

Note Numbers: The range 0–127 are semi-tone intervals covering 10 octaves of 12 semi-tones plus 7 semi-tones. No commercial keyboard covers this range. A typical five octave keyboard would cover the range 36–96 C to C, 60 being Middle C. Octaves 0–11, 12–23, 24–35 would sound at 36–47. Octaves 97–108, 109–120 and notes 121–127 would sound at 85–96.

MODES

The 16 channels can be used in four different modes compiled from OMNI ON/OFF, POLY and MONO and these cause the most confusion. In OMNI ON mode a receiver will recognise the messages on all channels without discrimination, which could sound quite chaotic. In OMNI OFF mode a receiver will accept information exclusively on a selected channel. POLY means that more than one note can sound at the same time. The number of notes is dependent on the number of DCOs, or Digitally Controlled Oscillators, the instrument, or synthesizer has and how they are employed.

Eight note chords are playable for one oscillator, and double this for two oscillators, but a tone produced by using both oscillators can only make eight notes sound. MONO means only one note will sound on each channel. Other notes, in a different voice, can sound from other channels. Typically one channel could play bass line, another could play the solo line, a third could play first harmony, etc. One point to note here is that MIDI cannot turn a monophonic synthesizer into a polyphonic instrument.

MODE 1—OMNI ON, POLY
Voice messages are recognised in all voice channels and assigned to voices polyphonically.

MODE 2—OMNI ON, MONO
Voice messages are recognised in all channels and control only one voice monophonically. Only one sound is emitted.

MODE 3—OMNI OFF, POLY
Voice messages are recognised in the channel selected by the receiver and are assigned to sound polyphonically.

MODE 4—OMNI OFF, MONO
Voice messages are recognised in the channel selected by the receiver and are assigned to sound monophonically, and with a sequencer enables the assignment of different voices to individual channels, according to the capacity of the sequencer. This mode is useful if a polyphonic synthesizer is used to control monophonic synthesizers.

Normally, when power is first applied to a MIDI device it defaults to Mode 3. Most keyboards transmit and receive, or recognise only in Mode 3, while synthesizers are also able to utilise Mode 4. The latter are normally capable of altering messages received in Mode 1 to Mode 3 and those received in Mode 2 to Mode 4. Rhythm machines normally default to Mode 3 to transmit, but also recognise Mode 1.

There are two kinds of MIDI messages: Channel messages and System messages. Channel messages contain channel numbers, Voice messages and Mode messages. The most basic of these are Note On and Note Off. The Note On message includes what key and how hard it is pressed. The Note Off indicates what key is released. Key numbers can be assigned to the drum voices of a rhythm machine. Control keys such as vibrato and sustain are communicated as Control Change messages.

A MIDI Master device can deliver Mode messages to slave devices. Program Change messages are associated with tone colours or rhythm patterns stored in memory and vary with each instrument. Only by comparison can tones be matched. System messages can be set without setting a MIDI channel. These include Song Select, which are arrangements utilising the tones, or patterns stored in Program Change; Clock, which is set for Internal on the Master and MIDI on slave devices and the Start/Stop functions. Exclusive messages are used in the tone colour data of synthesizers or for communication of sequencer data. It is original for each manufacturer with its own ID number.

Shown right is a typical MIDI Implementation Chart supplied as a standard form with all MIDI instruments. This should be studied in conjunction with the channel message table.

MIDI THRU BOX

As previously stated MIDI THRU is a buffered duplication of the MIDI IN signal. Unfortunately, many manufacturers, such as Technics, Casio and Roland, do not include this socket. However, at its best it cannot match a MIDI THRU box, which allows any of the devices to be used as the Master and provides several MIDI THRU outputs. The simple unit to be described overcomes the lack of THRU outputs.

For reasons of safety and to ensure the absence of earth loops, the MIDI IN signal is opto-isolated. The interface uses five pin, 180deg, A-Type DIN sockets. MIDI IN uses pins four and five of the socket, where pin four is connected to the cathode of the isolator l.e.d. via a current limiting 220ohm resistor and pin five goes direct to the anode of the l.e.d. There is a protection diode across the isolator l.e.d. There is no earth connection. MIDI OUT has an earth connection at pin two and +5V at pin four via a 220ohm current limiting resisitor. The c.p.u. signal comes to pin five via a buffer, which is comprised of two inverters, followed by a 220ohm current limiting resistor. MIDI THRU is a duplication of this circuit, but connected to the MIDI IN at the c.p.u., see Fig. 6.

MIDI THRU boxes are simple devices, which are expensive to purchase from a dealer, yet simple and inexpensive to make for oneself. The box described here can cost as little as £1.30 for the Master/Two slave version, or around £3.50 for the Master/Five slave version, where 50 per cent of the cost is in the case.

MIDI IMPLEMENTATION CHART

Function		Transmitted	Recognised	Remarks
Basic Channel	Default Changed	1–16 1–16	1–16 1–16	Memorised
Mode	Default Messages Altered	Mode 3 X **********	Mode 3 POLY/MONO Mode 1–3, 2–4	OMNI ON/OFF ignored
Note Number	Range	36–96 **********	0–127 36–96	0–11, 12–23, 24–35=36–47 97–108, 109–120, 121–127=85–96 ●
Velocity	Note On Note Off	X X 9n v=0	X X 9n v=XX	XX=ignored
After Touch	Keys Channel	X X	X X	
Pitch	Bender	O	O	8 bits effective 0–12 half tones
Control	1 6 64 93	O X O *OX	O O O O	Vibrato Master Tune Sustain Pedal Chorus
Program Change	Range	O 0–63 **********	O 0–63 0–31, 32–63	0–31 preset 32–63 memory
Exclusive		O	O	Timbre, sequencer data and others
Common	Song Pos Song Sel Tune	X *OX 0–16 X	X X X	
Real Time	:Clock :Commands	O O	O (Midi mode) O	
Aux: Local ON/OFF Mes: All Notes OFF sag: Active Sense es: Reset		X O X X	O O X X	
Notes		*OX Whether or not the data for these items can be transmitted can be set. ● Numbers change when transpose switch used.		

Mode 1: OMNI ON, POLY Mode 2: OMNI ON, MONO O: YES
Mode 3: OMNI OFF, POLY Mode 4: OMNI OFF,MONO X: No

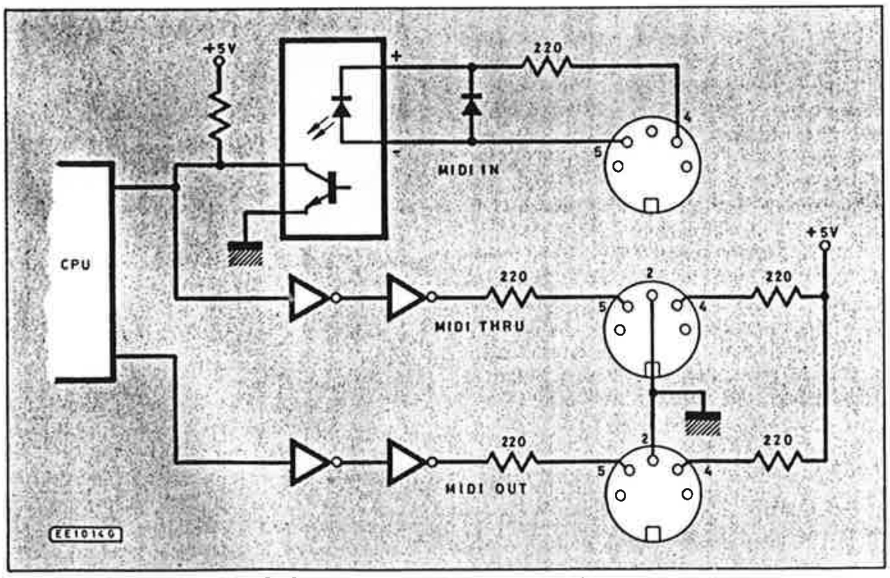


Fig. 6. Connection of MIDI THRU at the c.p.u.

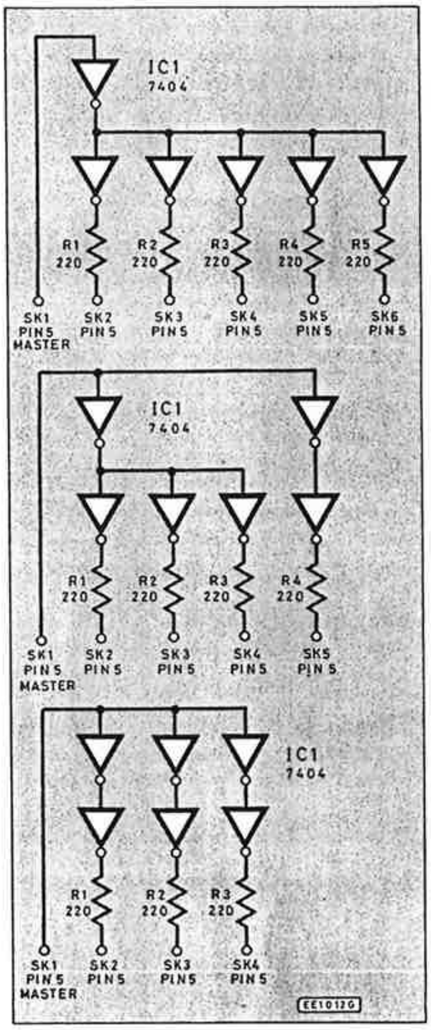
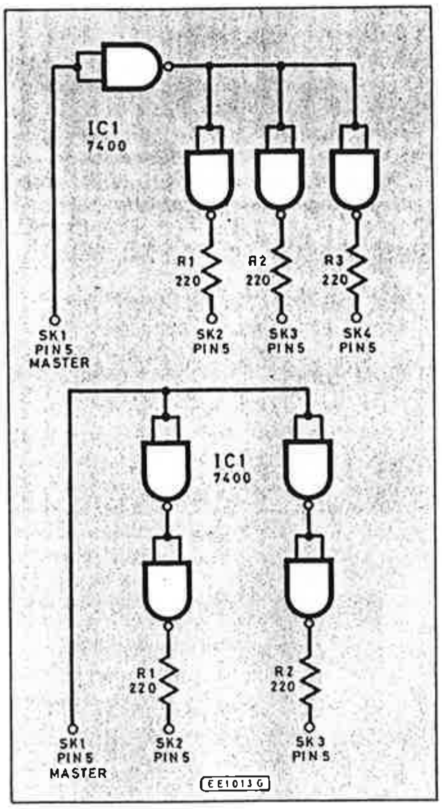


Fig. 7 (above). The 7404 Hex inverter connections for master and five, master and four, master and three THRU boxes. (Below) The 7400 quad two input NAND connections for master and three or master and two THRU boxes.



CIRCUIT AND CONSTRUCTION

Whilst guidelines are provided later on for constructing boxes of several forms of outputs, the description here is for a Master and three slaves, which can serve a keyboard, synthesizer/sequencer, rhythm composer and computer, or similar set-up. The unit is constructed in a potting box measuring approximately 100 × 50 × 25mm. Because of the simplicity of the unit, the circuit description and construction will be described together.

Four sockets are mounted on the potting box to provide access for the MIDI OUT signal from the Master source and three for distribution. The ground rail is run through

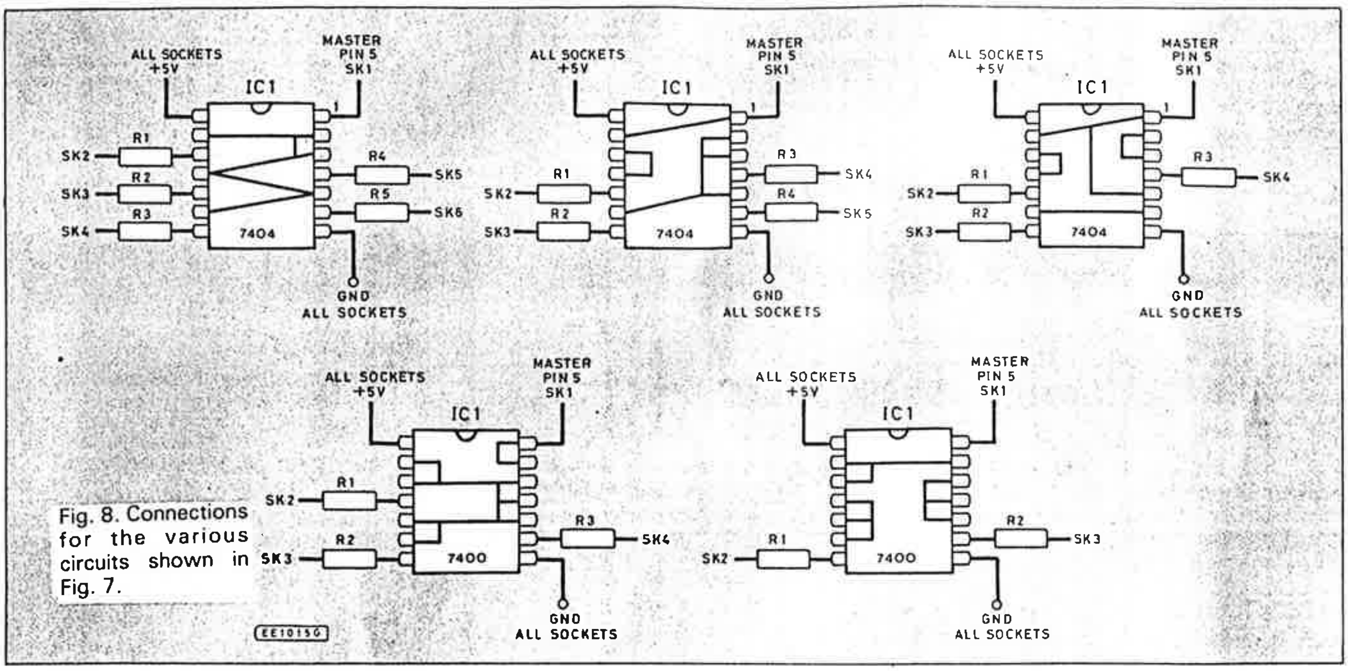


Fig. 8. Connections for the various circuits shown in Fig. 7.

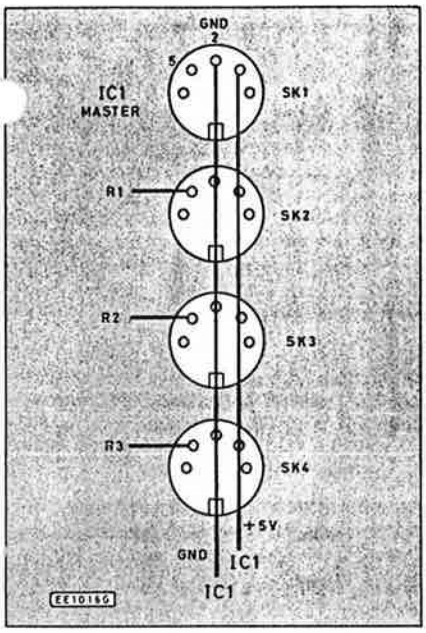


Fig. 9. Connections of the DIN sockets.

COMPONENTS

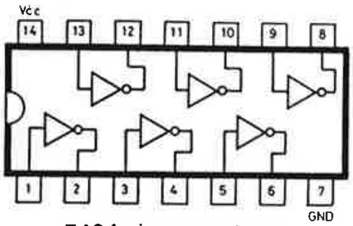
For Master/Three slave version—see text

Resistors
R1 to R3 — 220 $\frac{1}{4}$W carbon (3 off)

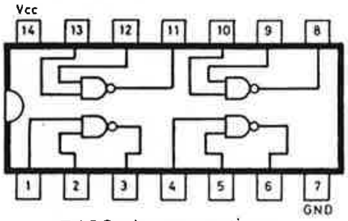
Semiconductors
IC1 — 7400 or 7404 (see text)

Miscellaneous
SK1 to SK4 (4 off) five pin 180 degree A-type DIN sockets; Connecting wire; potting box approx 100 x 50 x25mm.

Approx. cost Guidance only £3 (see text)



7404 pin connections.



7400 pin connections.

pin two and the ground pin on all four sockets. As the +5V at pin four already has a current limiting resistor at the Master source there is no need for any in the box, therefore pin four of all sockets can be connected with a single rail. Pin five of the Master socket must be connected to all buffer inputs and pin five of the MIDI THRU sockets will each require a 220ohm current limiting resistor. They will be used as connecting leads between buffer outputs and sockets and should be soldered to the i.c. before insertion in the box.

It is up to the individual whether to use a 7400 quad two input NAND gate with its inputs connected together and treated as inverters, or to use the 7404 Hex inverter (Fig. 7). If the 7400 is used, the i.c is turned on its back and the output from one inverter connected to the inputs of the other three inverters. An insulated single strand wire is soldered to the first inverter input for later connection to pin five of the Master socket, 220ohm resistors are soldered to the outputs of the other inverters, to be connected to pin five of individual THRU sockets.

If the 7404 is used, the inverters are connected in three inverter pairs and treated similarly. Single strand red and black wires are soldered to pins 14 and seven respectively for connection to the +5V and ground rails of the sockets. Having linked inverters and soldered connecting leads and resistors, the i.c. is laid on its back in the box, in a convenient place and the leads trimmed to a suitable length before soldering to the sockets (Fig. 8). The leads should hold the i.c. firmly, but it can be stuck down if required. After testing, a thick piece of card, or board can be cut to be stuck neatly into the bottom of the potting box. The Master socket should be clearly marked.

The diagrams (Figs. 8 and 9.) show the pin side of the sockets and the bottom view of the i.c.s. The ground and +5V rails can each be a short length of tinned wire which passes through the holes in the socket pins. □