MIDI MATRIX 2

PROJECT

Neil Johnson describes the design and construction of a versatile eight-channel MIDI routing unit for the home or small studio.

PART 2

The hardware described last month is only half the story - without the software it is just a box of bits. This section describes what the software does, how the various menus work, and what the various modes of operation do.

The overall structure of the software is presented in Figure 10. Do not be put off by the appearance of a scheduler - far from adding complexity, it actually reduces complexity by helping separate the various software tasks and managing all timing-related activities. It is a small co-operative multi-tasking real-time operating system (RTOS), and in this application provides timing accuracy of approximately 1ms.

Each task responds to events sent to them from other tasks in the system, in a manner similar to the way Microsoft Windows operates. However, each task runs to completion before handing control back to the scheduler, so there are no overheads and headaches associated with pre-emptive multi-tasking RTOSes (resource locking, priority inversion, critical sections, semaphores, etc).

The purpose and function of most of the drivers should be fairly self-evident - the EEPROM driver talks to the EEPROM, the MIDI driver receives and decodes MIDI messages, and the Mux driver manages the MIDI routing multiplexers.

The button task/driver and the display task/driver are complicated by crossing the boundary between the two levels. The button driver interfaces with the button scanning hardware, while the button task repeatedly scans and debounces the states of all the buttons, posting events to the user interface (UI) task whenever it detects a button press.

The display driver likewise manages the low-level interface of the display driver, while the display task manages the multiplexing of the display data, as well as providing a range of services to the UI task for managing the display.

Both these tasks use the scheduler to

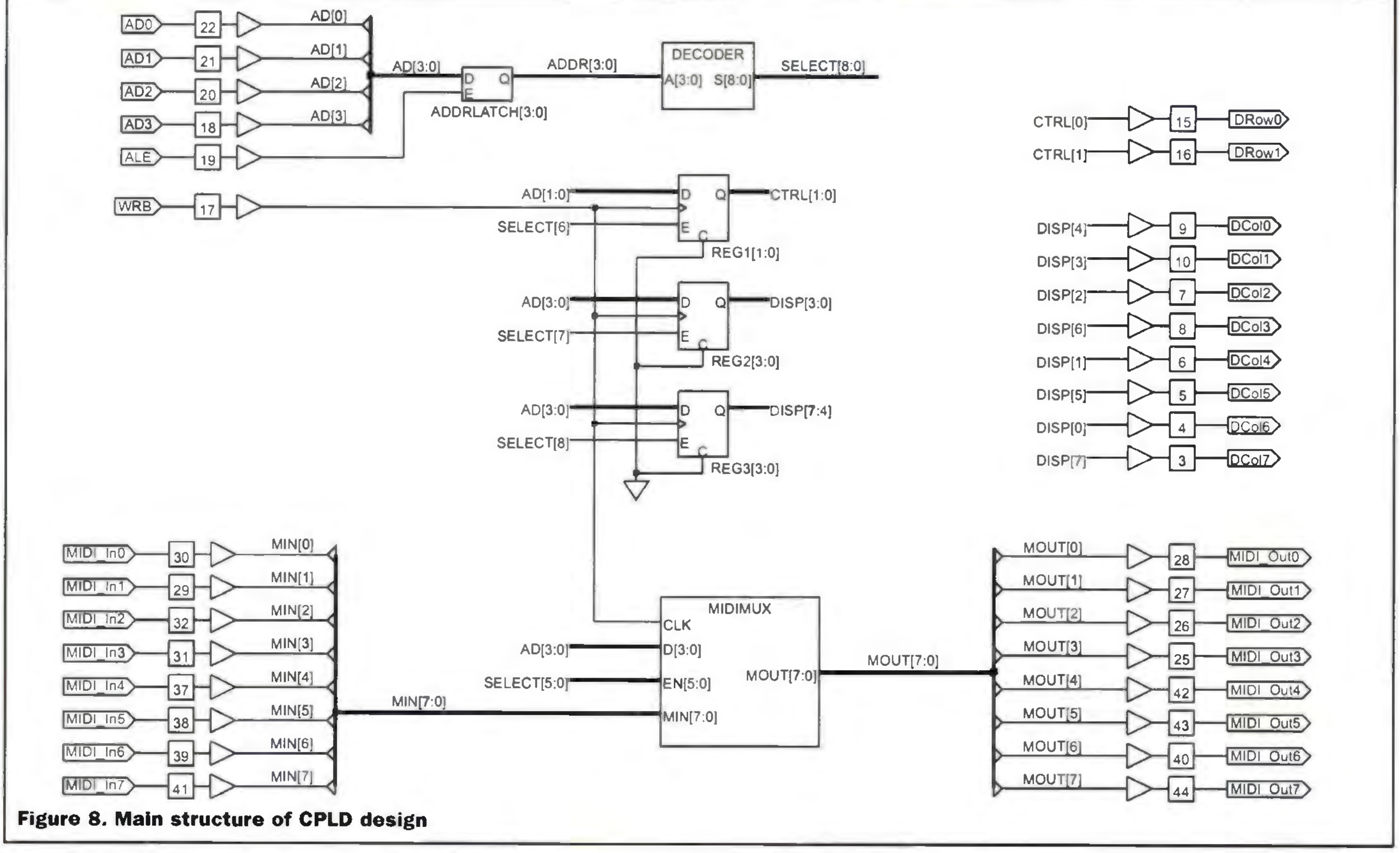


Figure 8. Main structure of CPLD design

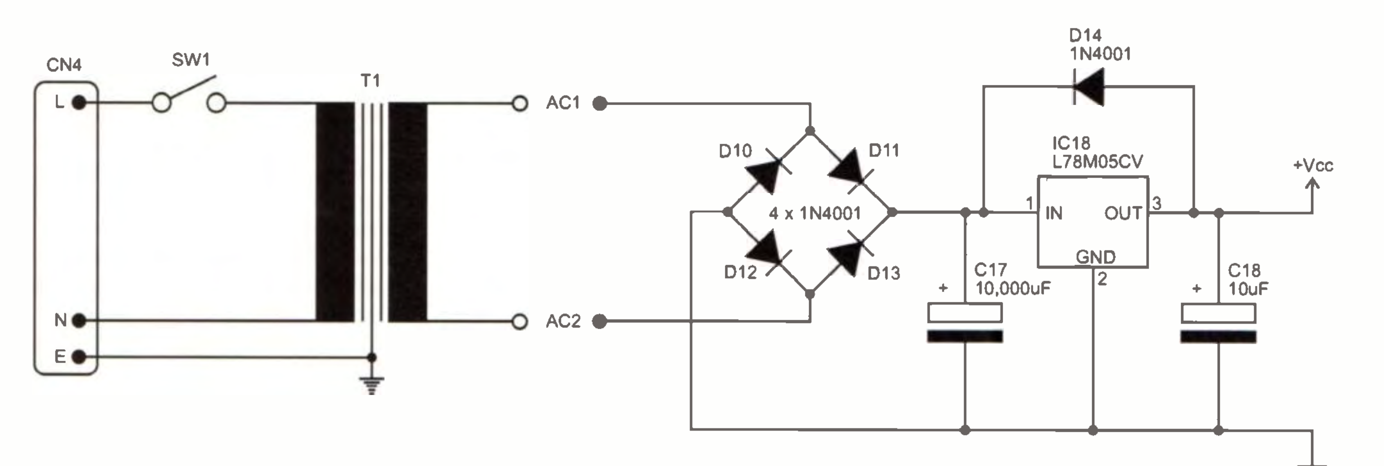


Figure 9. Power Supply Unit

provide timing control, either for scanning buttons or multiplexing the display. The button task repeatedly posts itself an event every 6ms, each time scanning another row of buttons. The upshot of this is that the buttons are debounced over a period of 48ms, allowing for switching transients due to the mechanical nature of the buttons. Likewise, the display task multiplexes the display every 4ms, completely refreshing the display every 16ms.

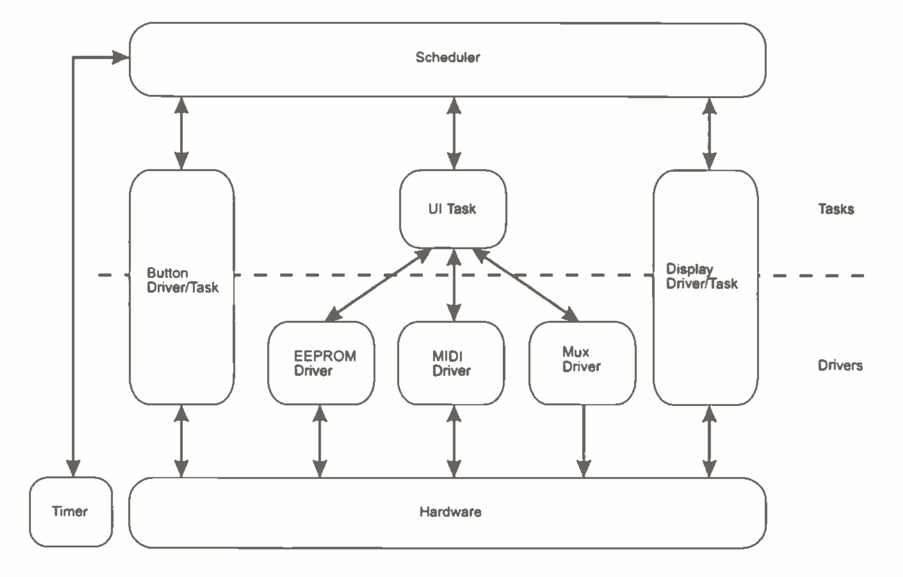


Figure 10. The modular software approach simplifies design, debugging and testing

The UI task is where the real meat of the software sits, and where everything to do with the user is concerned. The design of the UI covers both hardware (buttons, displays, LEDs) and software (menu pages, information display, prompting). A good UI combines these two in a way, which makes the equipment as easy to use as possible. Well, that's the idea anyway!

Today's Special

The heart of the UI system is a set of menu pages. Menu pages are displayed using a combination of the 2-digit 7-segment LED display, the two main mode select buttons to the left, and the sixteen channel select buttons on the right. Figure 11 shows the front panel layout.

The four main modes of operation are MIDI, Patch, Edit and Save, as shown if Figure 12. The MIDI mode shows the current MIDI channel on the display, and allows the user to select a new MIDI channel on which to listen for patch change commands. The Patch mode is for recalling a patch from the internal memory. The Edit mode is for editing the MIDI routing pattern, and Save mode is for saving a patch into the internal memory. Each of these modes is described in more detail in the following sections.

MIDI Mode

MIDI mode is entered by pressing the MIDI mode button. The button lights up to confirm the mode selection. The display shows the current MIDI input channel for receiving patch change messages, and the corresponding selection button lights up. In this mode the top row of buttons corresponds to MIDI channels 1 to 8, and the bottom row corresponds to channel 9 to 16.

A new MIDI channel is chosen by pressing one of the selection buttons. The new MIDI channel will be shown on the display and the corresponding selection button will light. The setting is also stored in the internal memory, and is reloaded when the unit is turned on.

The MM2 is configured to listen to the MIDI messages coming in through input channel 8. MIDI Patch Change messages, which have the format 0xCn mm (where n is the MIDI channel number, and mm is the new patch number, in the range 0 to 63), will select a new patch if the MM2 is in Patch mode.

Patch Mode

This is the default mode of operation. To add a little bit of complexity to the program, there are two patch modes - Patch Select mode and Patch Query mode. The default is Patch Select mode, and is entered whenever you change to Patch mode. It is indicated by the Patch mode button LED being continuously lit.

The selection buttons allow you to select one of the sixty-four patch memories, and the display shows the currently selected patch. The current version of software does not store the last used patch in memory, so the unit always starts with patch 11 loaded. The sixty-four patches are numbered in a slightly funny manner, using the digits 1 to 8. The patch numbers start at 11, 12, 13, 14, 15, 16, 17, 18, then jump to 21, 22, 23, and so on, all the way to patch 88. The first digit is selected from the top row of buttons, and the second digit from the bottom row.

The Patch Query mode shows the routing arrangement for the patch. Pressing the Patch button moves the unit back and forth between Patch Select and Patch Query mode. Patch Query mode is indicated by the flashing Patch button flashing. In this mode, pressing one of the output select buttons highlights that button and the corresponding input that is routed to that output.

Edit Mode

Configuring the MM2, and being able to store those settings in non-volatile memory available for instant recall, is the heart of the system. The Edit mode, together with Save, manages this part of the system.

The Edit mode is entered by pressing the Edit button. The patch number display flashes to show that you are editing the

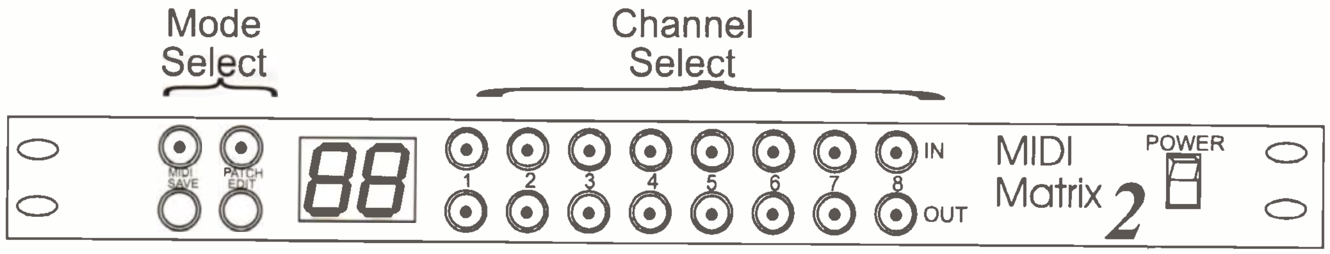


Figure 11. The MIDI Matrix 2 front panel

patch routing. Editing itself is quite simple - select an output, then choose the input that you want connected to that output. The selected buttons will light up to confirm the new configuration. Editing changes can be abandoned by pressing the Patch mode button, putting the unit back into Patch Select mode. Any changes to the patch will be lost and the original patch will be reloaded from memory.

Save Mode

Saving the patch requires two steps. First, pressing the Save button puts the unit into Save mode, indicated by all the select buttons and the patch number display flashing. In this mode you can select the patch location into which the new patch will be stored; it does not have to be the same as the one you started from.

Once the new patch number is selected, the patch data is saved in memory by pressing the Patch mode button. Pressing the Edit button puts the system back into Edit mode without saving the patch. From there you can either continue editing, or abandon the changes and return to Patch Select mode.

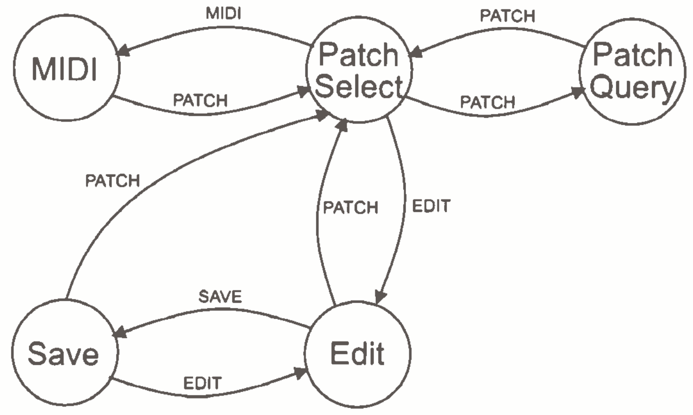


Figure 12. The operating modes of the MM2

The Patch Select-Edit-Save sequence can also be used for copying patches from one location to another. Start in Patch Select mode and choose the source patch. Then press Edit followed by Save, enter the new patch number, and press Patch. The patch has now been copied into the new location. Unedited patches default to all outputs connected to input 1.

Remote Control

The MM2 can be controlled remotely as well as from the front panel, albeit in a simpler manner. When the unit is in Patch Select mode patches can be selected by Program Change messages transmitted on the programmed MIDI channel connected to input channel 8. Of the 128 possible Program Change messages, the bottom half (0-63) are used directly, while the top half (64-128) are mapped onto the bottom half by subtracting an offset of 64. So, for example, patch number 64 maps onto patch number 0, number 65 onto number 1, etc.

Also, remember the strange patch naming system starting at 11 and finishing at 88? This can lead to some confusion, in that to change to MM2 patch number 12 you need to send a Program Change message with the value 1. Ouch! Why is this?

The patches are arranged in eight banks of eight patches, giving a total of 64 patches. The eight banks are numbered 1 to 8, and each patch in the bank is also numbered 1 to 8.

Some synthesisers (for example, the Roland Super JX) use a similar scheme, numbering the banks A through H and the individual patches 1 through 8, producing a

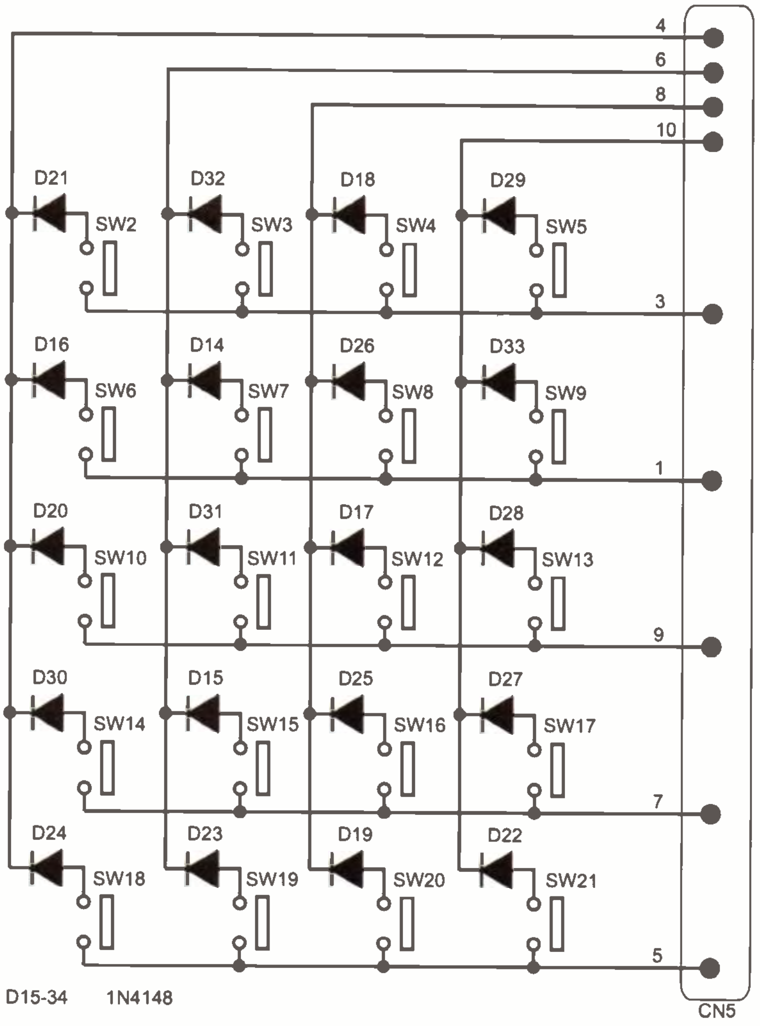


Figure 13. Front panel push button matrix

naming scheme like A7, H4, etc. Others, including the Yamaha SY77, split the patches into four banks (A to D) of 16 patches (1 to 16).

The formula for calculating what the decimal equivalent number is for each MM2 patch location is shown below.

$$\text{Patch} = 8 \times (\text{LeftDigit} - 1) + (\text{RightDigit} - 1)$$

So, for example, MM2 patch "47" corresponds to decimal patch number 30. If using a keyboard, either a synthesiser or a master keyboard, using the front panel patch select buttons reduces the whole affair to button jabbing.

Up Front and Personal

The front panel is built up from a second PCB. Figures 13 and 14 show the button and LED scanning circuits respectively.

The button scanning matrix (Figure 13) connects directly to the microcontroller through CN5. Each button has a blocking diode to stop any current flowing through the switch if it accidentally pressed while a neighbouring row is being scanned.

The LED matrix (Figure 14) is similar in design, with the thirty-two LEDs arranged in four blocks of eight. None of these LEDs are identified in the parts list - they are combined as parts of other components. Fourteen of them make up the two seven-segment displays, with the remainder being part of the push buttons.

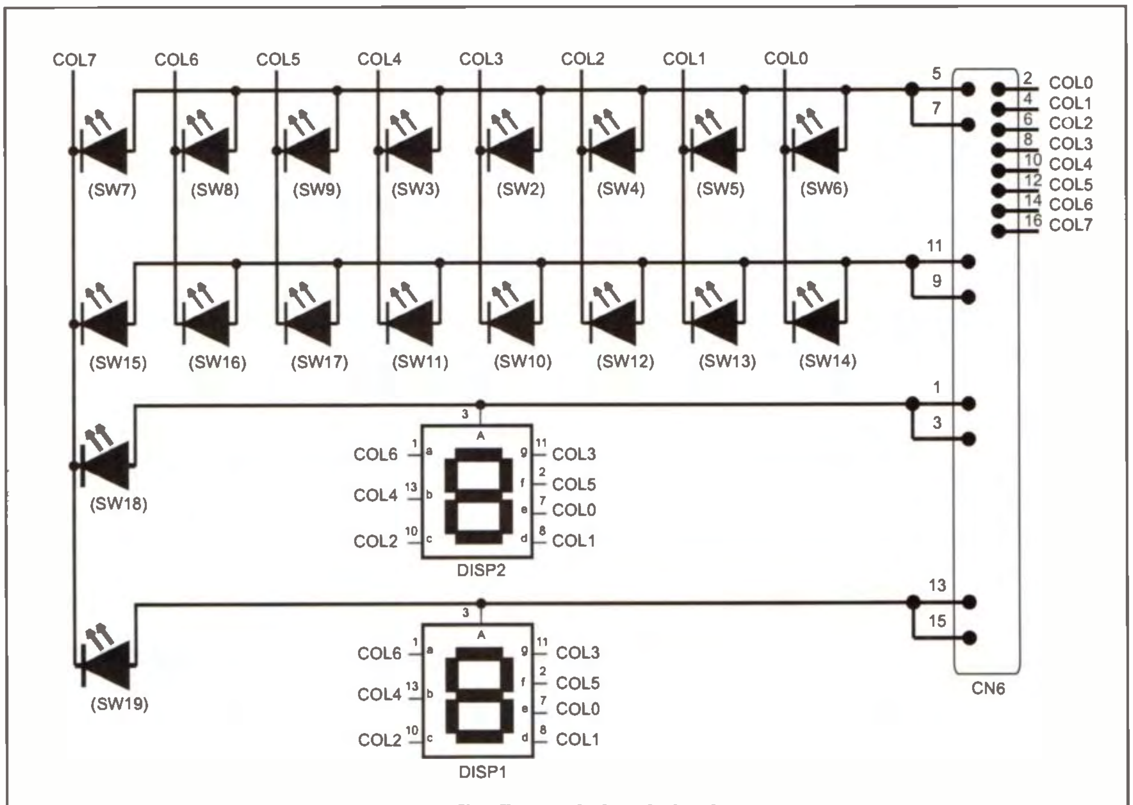


Figure 14. Front panel display schematic. The figures in brackets show which buttons the LEDs are mounted in.

Construction

The MM2 consists of three distinct parts - the main PCB, the front panel PCB, and the case and associated internal wiring. We will start with the simplest part - the front panel PCB, then follow with the main PCB, and complete the project with the case and remaining wiring.

The front panel PCB component layout is shown in Figure 15. It is recommended that a through-hole plated (PTH) PCB is used for ease of construction, although this is not necessary for successful completion of this project (all the author's PCBs are double-sided but not PTH).

The board is populated with twenty push buttons (two of which do not have internal LEDs), fifteen through-board links, two IDC connectors, two seven-segment LED displays and twenty diodes. All but the two IDC connectors are mounted on the component side of the PCB; the connectors are mounted on the rear.

Begin with the through board links and the diodes. Follow with the two displays, making sure they are seated (a) the right way round, and (b) evenly aligned with respect to each other and the surface of the PCB - otherwise they will look wonky and uneven when mounted behind the front panel. Complete the component side with the twenty push buttons. Note that items SW20 and SW21 are different from the others in not having internal LEDs, and that items SW18 and SW19 have red LEDs, while the remainder has green LEDs.

The two IDC connectors are mounted on the rear of the front panel PCB to allow easy routing of the connecting cables from the main PCB. All solder joints to the two connectors are made on the component side.

The component layout for the main PCB is shown in Figure 16. It is of a more traditional construction, with all components mounted on one side and solder applied to the other. Start with the through-board links (for non-PTH boards) and continue with the resistors and small capacitors. Then follow with the larger capacitors and connectors.

Leave out the semiconductor devices until last. It is recommended that a socket is used for IC15 (the EPROM), and one is definitely needed for IC16 (the CPLD). Again, start with the smaller diodes, then the transistors, the direct-soldered devices, finishing with the two sockets.

At the end of soldering give the board a careful examination for solder bridges and splashes, poor solder joints and other debris. Ideally, give the board a clean with flux remover. The voltage regulator, IC18, should be mounted on a small aluminium heatsink - find something suitable from your junk box. At the least, something about 1-inch square with some fins, painted matt black.

The third PCB is used for mounting the mains transformer. The component layout is shown in Figure 17. The transformer itself is soldered directly to the board, with the connections made as both ends. The terminal pads are designed to accommodate 10mm-spaced PCB screw terminal blocks, but these are optional and the wires can be soldered direct to the PCB, or PCB pins.

Driller Killer

The next major stage of construction is drilling out the various round and rectangular holes in the case. Three of the case's six panels require holes: the front panel needs holes for the mains switch, push buttons, seven-segment LED display and the mounting holes for the front panel PCB; the bottom panel needs mounting holes for the main PCB and the transformer. The rear panel needs holes for the sixteen MIDI connectors and the mains power connector.

Taking the front panel first, the complete mechanical drilling detail is shown in Figure 18. There are a total of thirty holes to drill - twenty push buttons, eight mounting holes, one display cutout and the mains switch cutout. A distinction is made between a hole (made with a drill) and a cutout (a non-round hole). Also note that because the majority of the holes are related to component positions on the front panel PCB extra care must be taken in the preparation of the front panel.

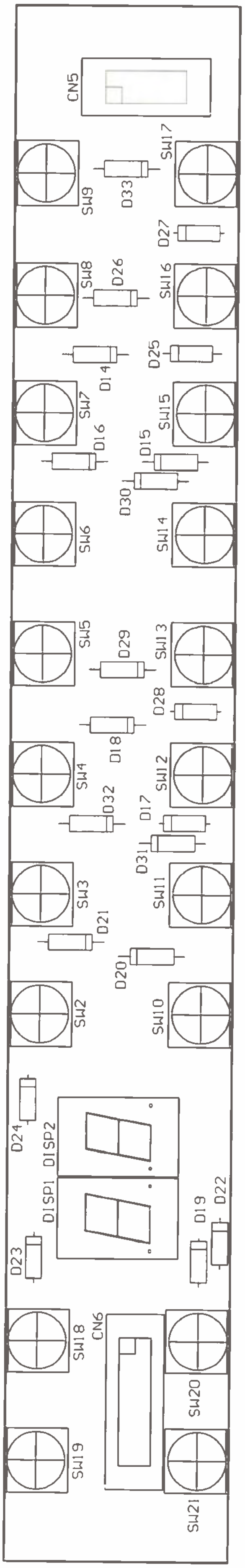


Figure 15. Front panel PCB component overlay. Note that CN5 and CN6 are mounted on the solder side of the PCB

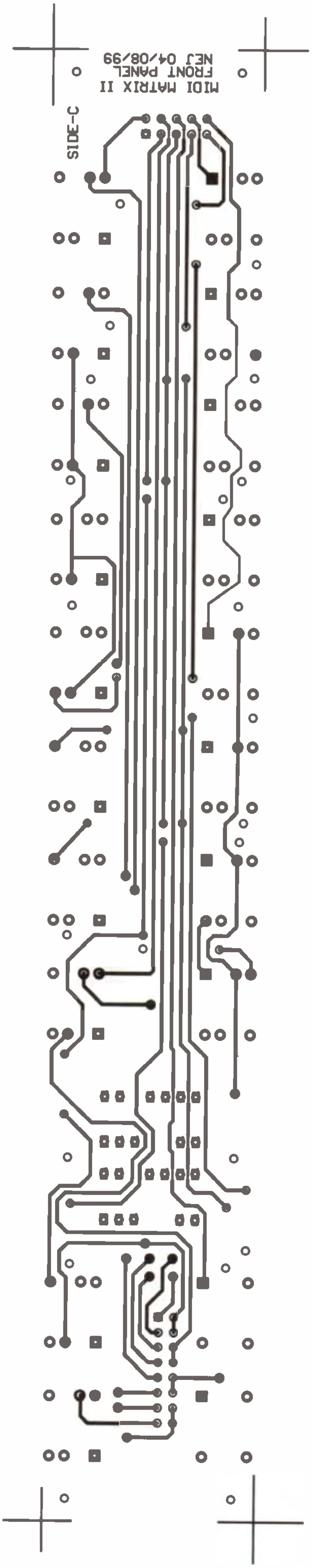


Figure 15a. Component side foil pattern

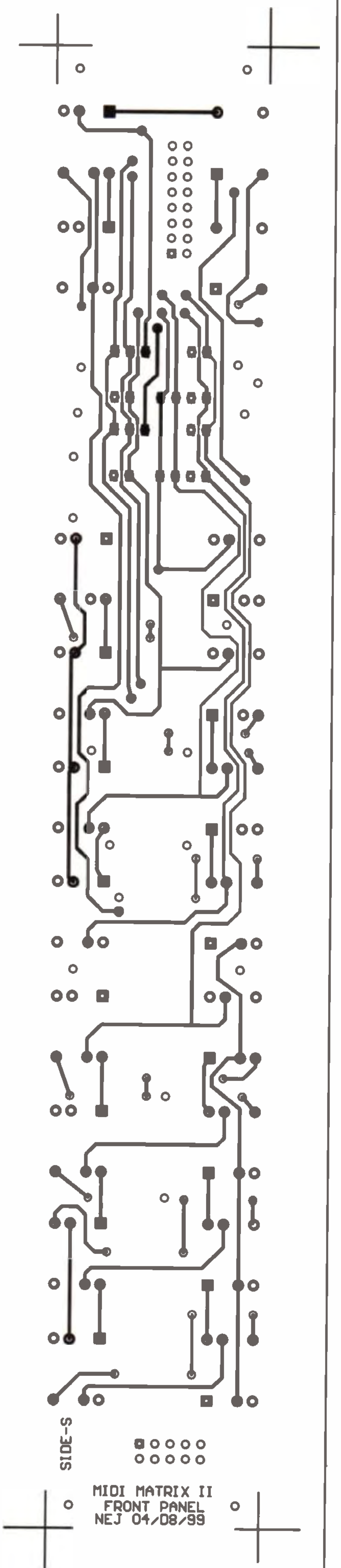


Figure 15b. Solderside foil pattern

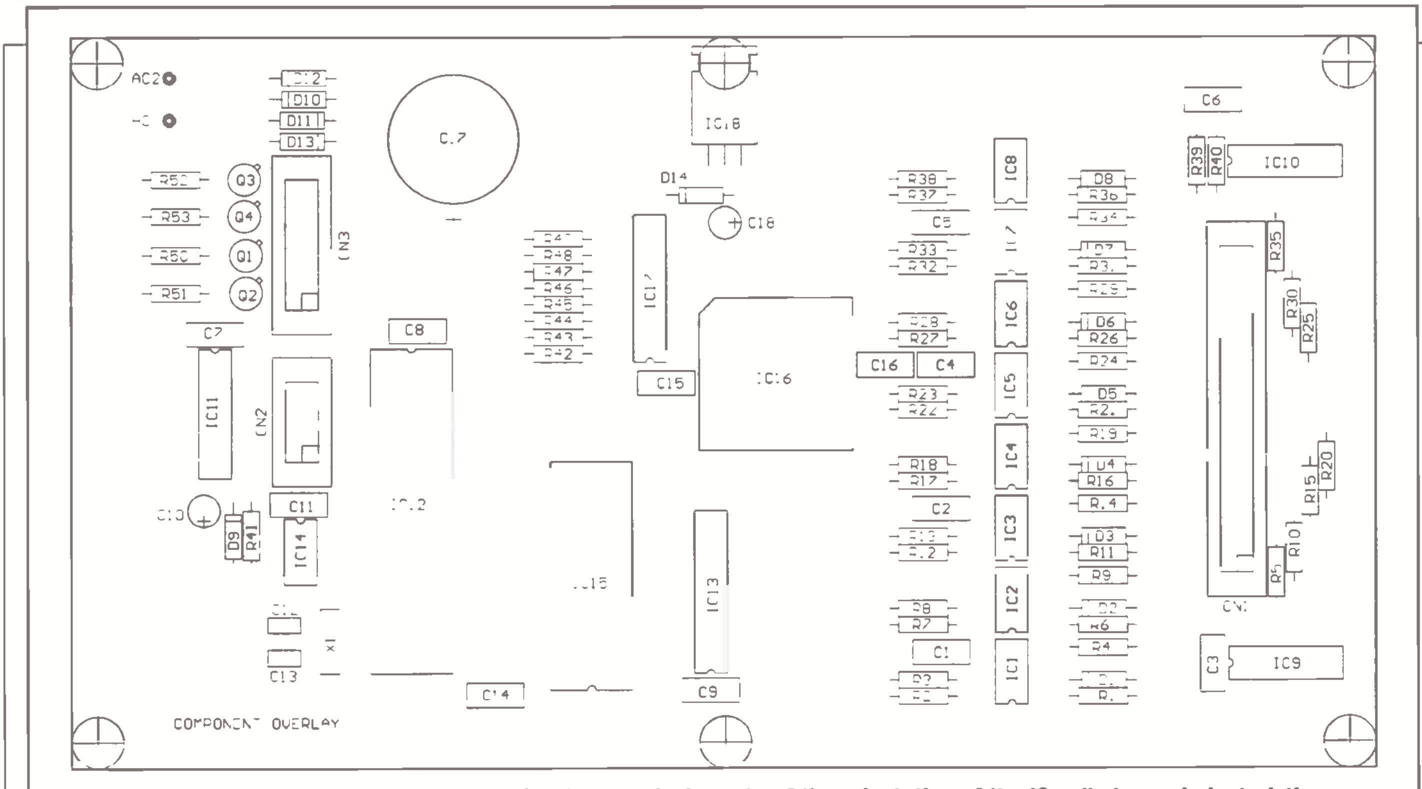


Figure 16. Component overlay for the main PCB. Take particular note of the orientation of the ICs, diodes and electrolytic capacitors. Note: Figure shown at 85%

Having said that, the key is in the marking out - taking extra time to make sure the hole marks are in the right place prior to drilling will be time well spent. It is especially recommended that a surface plate and surface gauge be used to mark out the front panel. These two tools used together will ensure that your scribing lines will run parallel to each other and to the sides of the panel.

The author's unit, as seen in the photos, uses a second front panel for cosmetic appearances. This thinner panel is glued on to the front of the main unit, covering the mounting screws. It is engraved and machined from precise computer-generated drawings to give a professional appearance. The panel is available from the author at the address given in the Parts List.

The rear panel, Figure 19, shows the location and dimensions of the sixteen MIDI sockets and the mains input connector. Again, time spent in marking out will help avoid mistakes, and produce a professional-looking unit.

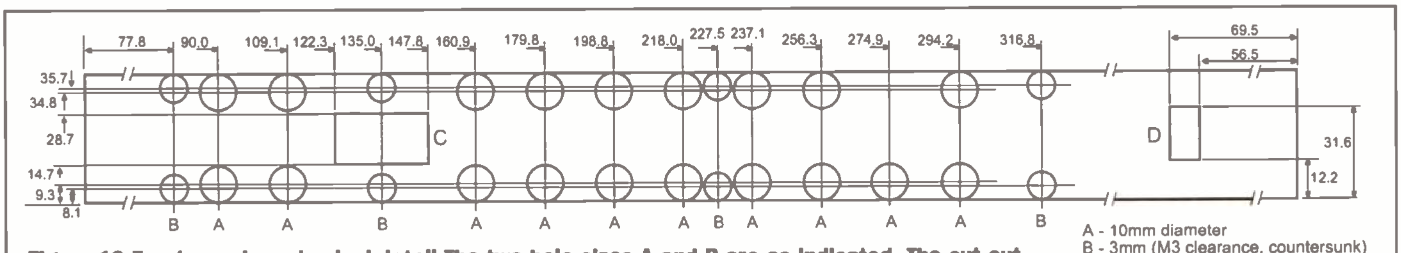


Figure 18 Front panel mechanical detail The two hole sizes A and B are as indicated. The cut out for the display is marked 'C' and mains switch 'D'. All holes are deburred before final assembly.

Finally, Figure 20 shows the internal layout of the case, showing the main PCB, the mains transformer, and the wiring between the PCB and the front and rear panels. The large smoothing capacitor, C17, is fixed to the bottom with a sticky pad and cable tie. It should be wired to the PCB with two short lengths of heavy (32/0.2mm) wire.

The internal wiring schematic is shown in Figure 21. Take special care with the mains wiring, and it is STRONGLY recommended that the wiring is check by a qualified electrician before any mains voltage is applied.

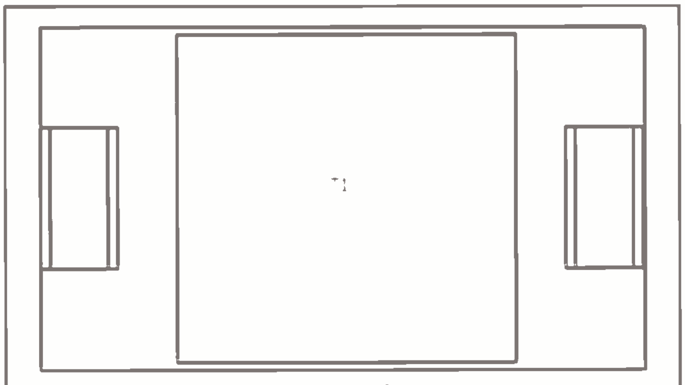


Figure 17. Transformer mounting PCB overlay with screw terminals at each end

CAUTION: this unit uses mains voltage for its internal power supply. MAINS KILLS—TAKE CARE. Following the wiring diagram exactly, and check the circuit carefully BEFORE connecting it to the mains. Too many musicians have been killed by mains electricity already—making music is supposed to be lively, not deadly.

Testing

The MM2 routes digital MIDI signals from eight inputs to eight outputs, employs an eight-bit microcontroller to control the user interface, keep a set of sixty-four patch configurations in non-volatile memory, receives and interprets MIDI patch change messages, and configures the routing matrix for each patch. With everything under computer control there is no setting up to do.

The main source of potential problems is in the wiring between the back panel MIDI sockets and the main PCB. A total of forty wires are soldered onto the backs of DIN sockets, so there is ample opportunity to get some of them wrong. A good test is described here.

Turn the unit on and check the display does a one-second lamp test (all LEDs on) then shows Patch mode with patch 11 loaded. At first, the data in the EEPROM will be uninitialised; the MM2 will set this to

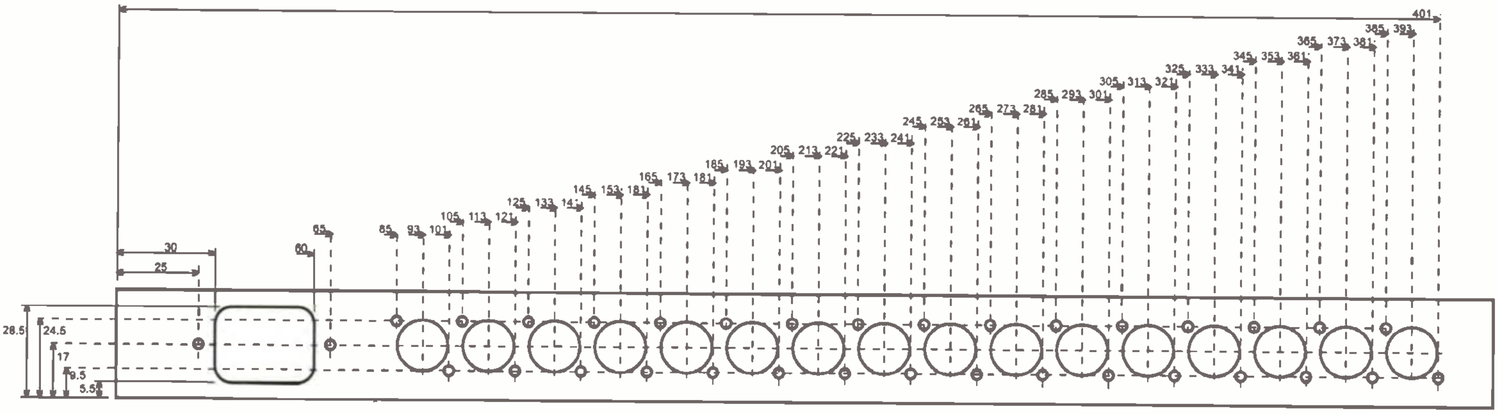


Figure 19 Rear panel mechanical drilling details. All small holes are 3mm in diameter; the larger round holes are 15.5mm in diameter. The cut-out for the IEC mains connector has 5mm radiused corners.

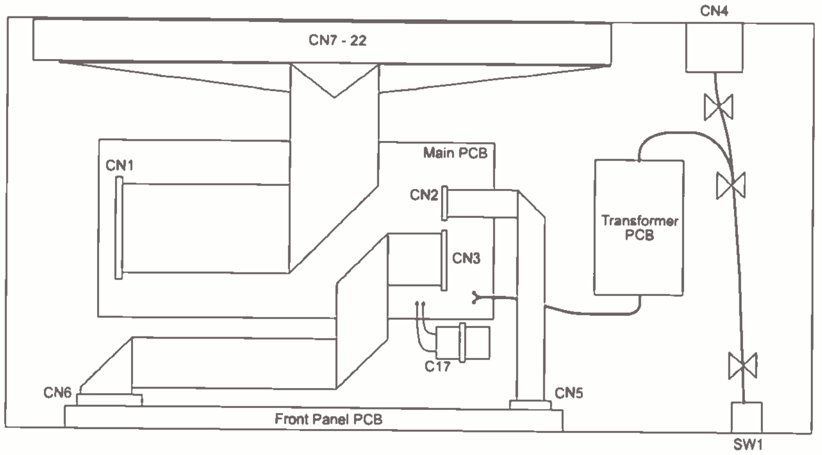


Figure 20 Internal layout. Careful folding of the ribbon cables ensures a neat layout. The mains wiring should be secured to the case at the points shown. C17 is secured with a cable tie and clip next to the main PCB.

the default of input 1 connected to all outputs. Enter Edit mode and route each input to its corresponding input (1 to 1, 2 to 2, etc). Then with a MIDI keyboard and a synthesiser, connect them in turn to each input-output pair and confirm that the synthesiser receives messages from the keyboard - pressing a few keys should trigger the synthesiser into making a sound.

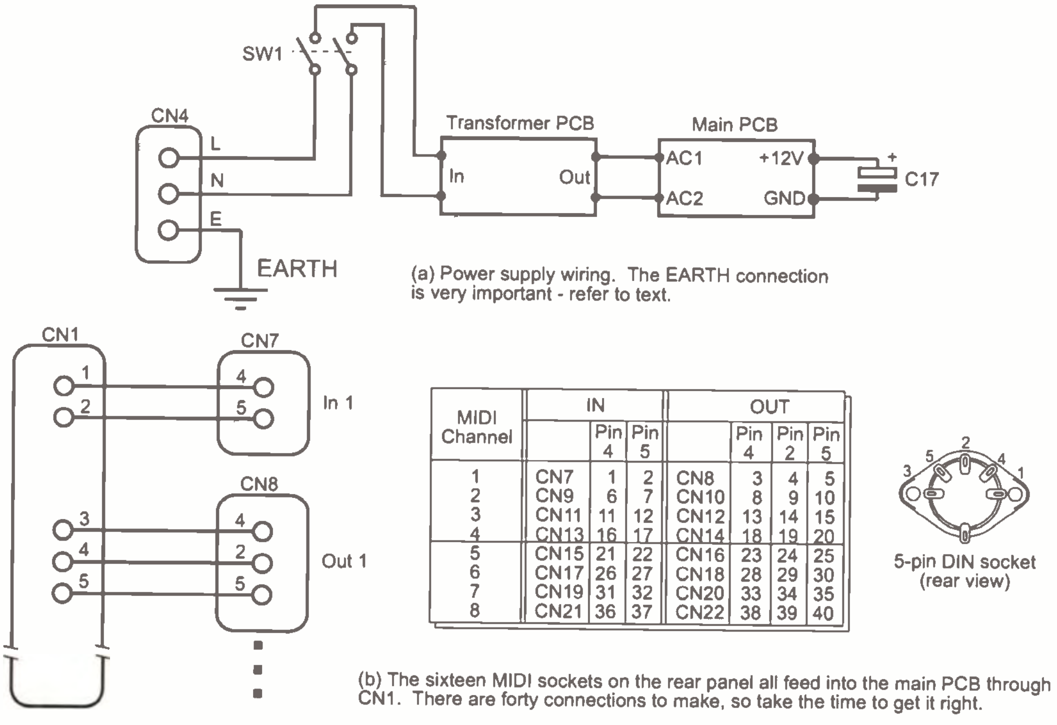
Since all MIDI inputs and outputs are electrically isolated thanks to the opto-isolators, any problems with the MM2 will not harm the keyboard or synthesiser.

Applications

The MM2 is a very flexible programmable MIDI routing unit. It can store up to sixty-four patches of routing information, any of which can be selected either from the front panel or remotely via MIDI. It solves one of the major problems of MIDI - any studio with two or more MIDI masters (anything from a master keyboard, synthesiser, computer, sequencer, etc) will at some point need to change the MIDI data path (it's "topology" in techno-speak).

The simplest use of the MM2 is between several MIDI masters and slaves. However, some devices can be both master and slave. For example, a workstation includes a synthesiser, keyboard, sequencer and, typically, a disk drive. The keyboard or sequencer generates MIDI data to drive the synthesiser, or it can be disabled to allow the internal synthesiser to be operated from an external master.

Another example is a sampler. Normally, it is operated from a keyboard or sequencer. However, transferring samples from a computer to the sampler requires the computer to be the sampler's MIDI



(a) Power supply wiring. The EARTH connection is very important - refer to text.

MIDI Channel	IN			OUT			
		Pin 4	Pin 5		Pin 4	Pin 2	Pin 5
1	CN7	1	2	CN8	3	4	5
2	CN9	6	7	CN10	8	9	10
3	CN11	11	12	CN12	13	14	15
4	CN13	16	17	CN14	18	19	20
5	CN15	21	22	CN16	23	24	25
6	CN17	26	27	CN18	28	29	30
7	CN19	31	32	CN20	33	34	35
8	CN21	36	37	CN22	38	39	40

(b) The sixteen MIDI sockets on the rear panel all feed into the main PCB through CN1. There are forty connections to make, so take the time to get it right.

Figure 21 Internal wiring diagram showing (a) power supply wiring and (b) MIDI signal wiring from CN1 to the rear MIDI sockets.

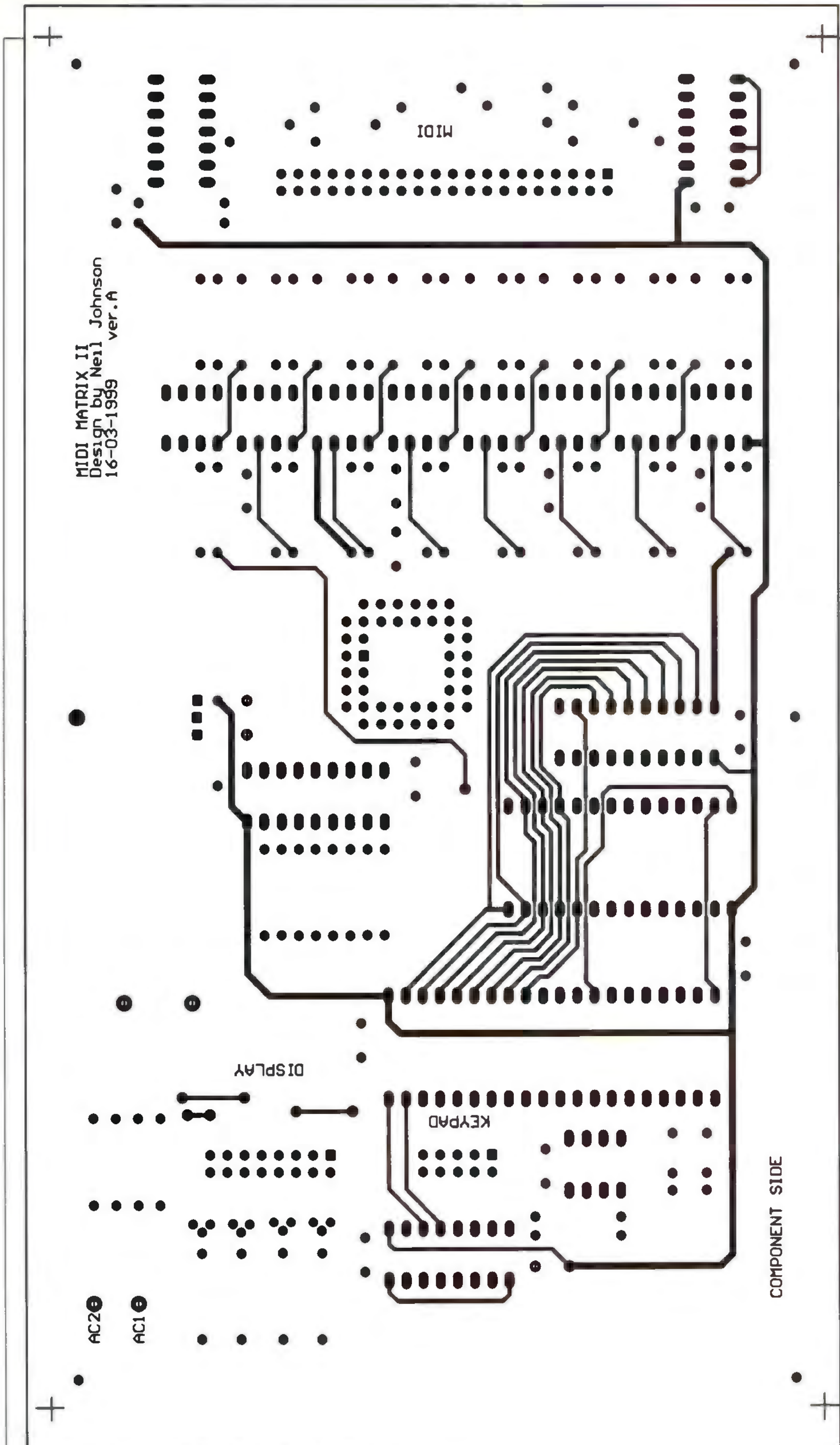


Figure 22. Component side foil pattern

PARTS LIST

Resistors (5%, 0.25W)	
R1, 4, 5, 6, 9, 10,11, 14, 15, 16, 19, 20, 21, 24, 25, 26, 29, 30,31, 34, 35, 36, 39, 40	220R
R2, 7, 12, 17, 22, 27, 32, 37, 42-49	330R
R3, 8, 13, 18, 23, 28, 33, 38, 41	10k
R50-53	680R
Capacitors	
C1-9, 11, 14-16	100n ceramic
C10, 18	10μF 16V tantalum bead
C12, 13	33pF ceramic
C17	10,000μF 25V electrolytic
Semiconductors	
IC1-8	6N139
IC9, 10	74HCT04
IC11	74HCT139
IC12	80C32
IC13	74HCT573
IC14	X25640P Farnell 563-845
IC15	27C512 see below
IC16	ispLSI 1016E-LJ80 see below
IC17	ULN2803A
IC18	L78M05CV
Q1-4	BC559
D1-9,15-34	1N4148
D10-14	1N4001
DISP1,2	HP 5082-7750 display Farnell 324-360
Miscellaneous	
X1	12MHz crystal
T1	Mains transformer Farnell 899-422
CN1	40way IDC header
CN2,5	10way IDC header

master, not the keyboard.

MIDI, like any form of data, can be processed to add, remove, or change some components of that data. There are MIDI processing units that operate on MIDI data to filter out or change the MIDI messages - everything from transposing a MIDI channel, moving data from one MIDI channel to another, blocking out certain MIDI messages, or adding new ones.

One approach taken to MIDI processing consists of arranging small blocks that do one thing well, so that a number of these blocks, when suitably arranged, can implement any MIDI filtering function required. This is where the MM2 could be used - by connecting each mini-processing module to an input-output pair it should be possible to arrange these units in any desired order simply by changing the routing path through these modules. Better still, if input eight is used for the MIDI input the current configuration can be remotely controlled. In theory, with seven separate processing modules, there are 127 different combinations of the modules (assuming that the order of the modules is irrelevant) - far more than there are patch locations to store them in, and certainly enough to accommodate most small studio uses.

Another interesting use of the MM2 is to manage a number of older MIDI instruments. In the early days of MIDI, the early 1980's, some MIDI instruments only listened on channel 1. One modern approach to fixing this problem is to use a MIDI processor to move messages from any channel to channel one for the synthesiser. But this needs one MIDI processor for every synthesiser, which could be quite expensive. One solution would be to use the MM2 to selectively connect the old synthesisers to the MIDI system only when they are needed. Of course, this only works when you only want to play one instrument

CN3,6	16way IDC header
CN4	IEC chassis plug
CN7-22	5-pin DIN chassis socket
SW1	Mains rocker switch
SW2-17	SPST green illum. push button Farnell 678-030
SW18,19	SPST red illum. push button Farnell 678-041
SW20,21	SPST push button Farnell 674-825
Case	Schroff 1U rack case – see below
Front Panel	Custom engraved panel – see below

Special Parts
Three items for this project are specialised or require special ordering details.

The recommended case for this project is available from Electrospeed. The case is item 20860-002. The top and bottom covers are item 30860-002 (two will be required). The custom engraved front panel seen in the photos is available from the author at the address below for £70 + postage. It is designed to be glued to the drilled-out front panel as described in the text.

The other two items are the programmed EPROM and the CPLD. For those with suitable programmers the data files obtained either from the author's website **www.njohnson.co.uk** in the Download section, or on disk from the author (free + postage). Otherwise the two parts are available ready-programmed from the author for £25 + postage.

Postage is £5 for the UK, £7 for Europe, and £10 elsewhere. Send cheques to:
Neil Johnson,
Dept. MIDIMUX2,
2 Chapel Field, Dixter Road, Northiam,
East Sussex, TN31 6PQ. UK.

Supplier Addresses
Below are the addresses for the suppliers used for this project. Website addresses are also provided for further reference.

Maplin Electronics Plc
www.maplin.co.uk
PO Box 777
Rayleigh
Essex
SS6 8LU UK

Farnell Electronic Components Ltd
www.farnell.com
Canal Road
Leeds
LS12 2TU UK

Electrospeed
www.electrospeed.co.uk
Boyatt Wood
Eastleigh
Hants, SO50 4ZY, UK

at a time, but it does give you remote control of when to change instruments.

It's a Rap

Puns aside, this just about ends this project for now. However, this does not end the continuing development of the MIDI Matrix. This project is a snapshot of an ongoing development of the MIDI Matrix theme. Over the coming years there will be software upgrades, newer versions with enhanced features, more channels, greater patch storage memory, and so on. For updates keep an eye on the author's website: <**www.njohnson.co.uk**>

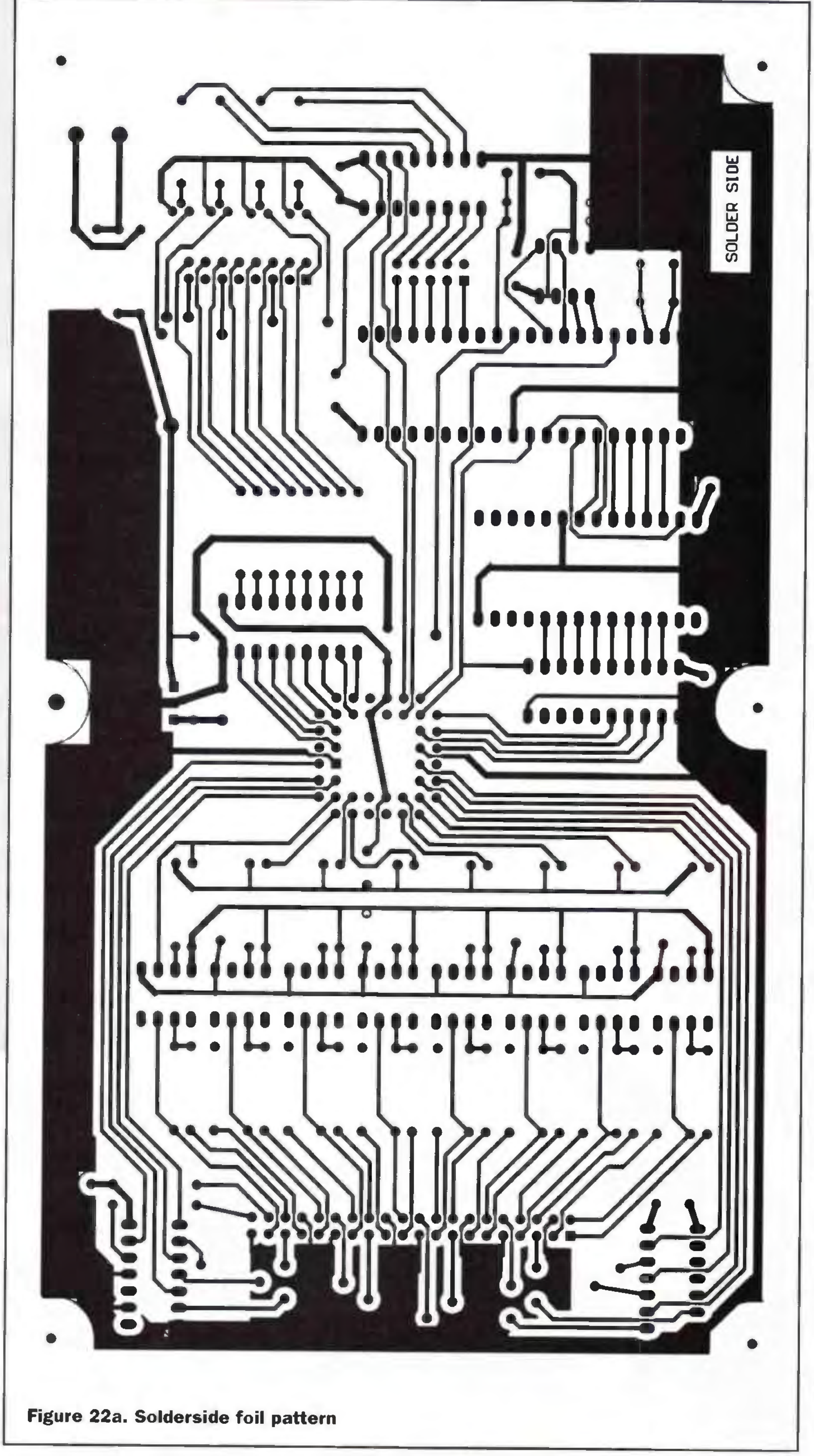


Figure 22a. Solderside foil pattern