

Oakley Sound Systems

midiDAC

Issue 3

Single Channel midi-CV Convertor

User's Guide

V3.41

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This is the issue 3 midiDAC in a natural finish Schaeffer panel. Note the new rounded corners. The toggle switches are APEM flat blade toggle switches available from Farnell. The round LED holders come from Maplin, whilst the knobs are the Rapid's 'matt black control knobs' for 1/4" fitting.

Introduction

The issue 3 midiDAC is a single channel midi to analogue convertor. This project is a joint development between Oakley Sound and Trevor Page. Trevor wrote the firmware for the processor used in this project.

The midiDAC is designed to drive any 1V/octave synthesiser or modular system. Let us first have a look at the different outputs available.

Gate: +5V gate or +15V gate

Pitch CV: 127 steps of 12 bit accurate pitch voltage conforming to 1V/octave (trimmable). Pitch bend may be added to this signal, and the maximum bend interval (up to one octave) can be adjusted from a front panel control.

Velocity: 0 to 10V proportional to midi note on velocity.

Pitch Bend: -5V to +5V proportional to pitch bend wheel position. 0V corresponds to a centred wheel.

Modulation: 0 to 10V proportional to modulation wheel position.

Aftertouch: 0 to 10V proportional to midi channel aftertouch.

CC # 100: 0 to 10V proportional to midi controller number 100.

Legato: This signal goes to +5V when two notes are played at the same time. This can allow slides to be activated at will; TB303 style. An optional external switch may be used to override the automatic activation of slide. Slide may be turned off by transmitting the standard midi glide/slide command.

The outputs are available on two sets of 4-way 0.1" connectors at the top of the board. Also featured is a 3-way header to directly feed the Oakley 'CV-velocity-gate' buss on the Dizzy board.

The design also features a midi thru circuit which is greatly improved on the previous issue midiDAC designs. The processor used in this project is a **PIC16F628** running at **4 MHz**. Although this PIC has a lower clock speed than issue 1 and 2 midiDAC boards, its onboard UART allows it to process midi data far more efficiently.

Please note: this product does not support the use of V/Hz or linear VCOs. These are found on some Yamaha and Korg analogue products, and just one Roland, the SH-2000.

Other Features

There is a note stack within the firmware to allow the midiDAC to remember notes pressed. Thus if two or more notes are pressed at the same time, the oldest notes will be remembered so that if the more recent notes are removed the pitch will return to the still pressed older notes.

The midiDAC also includes a TB303 style slide circuit. This can be turned either by engaging a switch, or by playing two notes at once. The pitch will glide up or down to the most recently pressed note. A pot can control the speed of the slide.

Note retriggering is an option that can be changed on the fly. A simple switch or link can be used to select whether it is on or off. Ordinarily, when a note is pressed the gate always goes high. However, if a second note is pressed while another is still held down, the pitch CV will change but the gate remains high. The envelope generators on your synth will not retrigger. This is typical of Moog synthesisers. It can be useful. The 'Retriggering' mode allows the gate to drop momentarily when any new note is pressed if there is a note already down. Thus, when the pitch CV changes, the envelopes will be retriggered, just like a normal note. This allows fast keyboard runs to be easily achieved.

The new suggested panel layout incorporates both the glide and re-trigger switches.

The midiDAC features a built in midi THRU port. This essentially produces a copy of the midi input signal which can be then fed to another midi unit. Previous issues of the midiDAC board used THRU drivers which added appreciable delays to the midi signal passing through it. These delays would build up if the midiDAC was used to drive another midiDAC. Using two older style midiDACs in series was probably alright, but driving a third from the THRU output of the second almost certainly did not work. The issue three midiDAC has a much faster THRU circuit. Both the opto isolator and the THRU buffer are high speed devices so longer midi chains can be tolerated. Even so, long midi chains are generally to be avoided in any system.

If you intend to use an older issue midiDAC with your new midiDAC in the same chain, then put the older one last in the chain.

Power Requirements

The module requires a split supply of +/-15V at around +40mA and -30mA.

Two sets of 0V or ground are required. This is to keep the analogue ground as distinct as possible from the noisier digital ground. Both grounds are required for correct operation of the midiDAC. They must be both connected to the power supply's star point or common ground bus.

If you have a complete Oakley Modular System, it is recommended that you do not directly connect the midiDAC's power supply to the same power bus as the modules. That means don't connect it to the Dizzy board. This is because pin 3 of the power inlet on the midiDAC

board is used as the digital ground and not the chassis ground as on other Oakley modules. Connection to the Dizzy distribution system will not damage the midiDAC module, but it may introduce unwanted noise on the power lines. Therefore please connect the midiDAC directly to the power supply output pins. This will, of course, be still connected to the same power rails as the modules but the **path** to the power supply will be separate and distinct.

To summarise this: One has to connect pin 1 of the PSU header to the positive output of your power supply. Connect pin 4 to the negative output of the power supply. Connect both pins 2 and 3 to the ground of the power supply. Use two separate wires for these ground connections, taking each wire back to the supply and connecting them together at the ground tag on the supply.

For connection with a MOTM power supply, we recommend that you connect the midiDAC to the distribution board on the MOTM supply directly. That is, not to a daisy chained distribution board far away from the MOTM supply.

The new issue midiDAC features some comprehensive protection mechanisms to prevent problem with the circuitry should the power supply fail. Earlier issues of the midiDAC were prone to failure of the 4066 and sometimes the DAC chips if the positive rail collapsed whilst still applying negative power. This unlikely event may have been triggered by inappropriate use of the power supplies or indeed spurious power up problems. The midiDAC-3 has been designed to withstand this sort of abuse.

The Printed Circuit Board

The PCB has been designed to fit within a 2U across MOTM style modular face plate. The size of the board is slightly smaller than older issues at 13.3 cm high and 11.1 cm deep. It has three PCB mounted pots to facilitate TUNE, BEND DEPTH and SLIDE RATE. The pots are spaced at the standard Oakley and MOTM spacing of 1.625".

Midi channel is selected by four lines in 'traditional' binary fashion. Thus midi channel can be switched by either onboard DIP switches or links, or by a 16 position rotary HEX switch mounted on the front panel. I tend not to change midi channel once I have built the unit, so I use DIP switches only. Because of this, there is no midi channel selector on the suggested front panel layout. However, the board is equipped to take a 0.1" header to allow simple connection to a rotary HEX switch.

The issue 3 PCB is double sided, has through plated holes, solder mask both sides and has full component legending. All boards sold by Oakley Modular are Pb free and RoHS compliant. Be aware that some of the resistors have their legending underneath the component. So once the resistor is in place it does make it difficult to identify the part's name. This had to be done to reduce the board surface area. However, all parts are labelled in a systematic fashion so that the smaller numbers are furthest left.

Power is admitted to the board via 0.156" Molex connector, just like the MOTM modules. (see section above)

The PCB has four mounting holes, one in each corner. However, using the midiDAC with the recommended pots and brackets, will give you sufficient support without the need for additional mounting hardware. The pots are now Spectrol 248 series, supplied by Farnell, CPC and Rapid Electronics here in the UK. The pot mounting brackets are specially made for the Oakley modular system and are available only from us.

Circuit Description

The midi data is electrically isolated by U7, a high speed logic output opto-coupler. The output of U3 is pulled up via R44 and drives two circuits. One is the PIC, the processing engine of the midi interface. The other is the midi THRU circuit. The latter is a circuit that simply copies the data seen on the MIDI input port and presents it to the midi thru output socket if one is fitted. U6 is a simple logic inverter gate, and two of these inverting gates in series produce a buffered version of the opto's output signal. Although U6 hardly affects the signal at all, it does give it a current boost allowing it to drive the midi lines via the standard 220R resistors.

Notice the midi out connector requires the middle pin to be grounded for shielding purposes. This is not allowed by the midi specification for the midi input socket, so grounding should only be provided on the thru socket.

The heart of the midiDAC is a preprogrammed PIC16F628. This is where Trevor's firmware is located. X1, a 4 MHz crystal provides the necessary timing for the PIC's internal oscillator. For more details on the operating system of the PIC see the 'Firmware Data' section.

Three of the PIC's output lines directly drive a 12-bit DAC, U9. The DAC is driven serially, and this is different to the old issue tbDAC where we used a parallel loading DAC. Although, the DAC is a 12 bit device we actually only use 7 bits. The other 5 bits of data are held low at the appropriate time in serial data stream.

Why use only the top seven? Firstly, midi data is arranged, in the main, in blocks of seven bits. For example there are only 127 notes that a normal midi keyboard can send out. Secondly, the PIC does not perform any CV scaling or tuning. This is sometimes used on other midi-CV convertors to generate ADSR and pitch bend information that is then merged in the digital domain to the pitch data. 14 or 16 bit DACs are required for this. We do all of our CV processing in analogue hardware. Thus slide time and pitch bend can be simply controlled by a pot or a trimmer.

So why not use an eight bit DAC? 8-bits, although it gives us 256 steps to play with, the accuracy of the steps is only plus and minus 1/512 of the highest output voltage of the DAC. That is an error of 0.2%. This may not sound much, but it does matter. In musical terms, this means that a semitone between one pair of adjacent notes, will be different to a semitone between another pair. Tim Orr, of EMS fame, reckoned that at least 10-bit accuracy was required for users not to **hear** any difference in the steps. I have chosen to use 12-bits, because 12 bit DACs are cheapish and easily available. Errors in a good 12-bit DAC will be negligible compared to VCO tracking errors.

The MAX551 is a current output multiplying DAC. This means two other things are needed to get it to convert digital data to an analogue voltage. Firstly, you need a very accurate reference voltage. This will set the maximum output voltage that the DAC circuit will supply. For the midiDAC the reference comes from a reference voltage chip, U3. This generates a stable 5.00V at its output.

A multiplying DAC will invert the reference signal applied at pin 19. So to get a positive output from our DAC, we have invert the 5V reference with U2 (pins 1, 2, 3). This is a precision op-amp, configured as an inverting amplifier to produce the required -5V.

The second item the DAC needs to create a voltage output, is a current to voltage convertor. This is strapped onto the output of the DAC, and in practice it simply consists of a single op-amp. This is U8. It needs to be accurate, have low drift over time and be fast settling. I have chosen an AD712 by Analog Devices. C19 provides stability.

With a -5V reference the output of the current to voltage convertor is a maximum of +5V. We need a higher level of signal than this, so we amplify the signal by exactly two. This is done with the other half of U8, which is configured as a non inverting amplifier of gain two. Notice the 0.1% tolerance resistors to set the gain. This is because we need to have accuracy here so that our pitch bend circuit works correctly.

The alert reader may well point out that we could have obtained a full scale output of 10V by providing the DAC with a -10V reference. This is true, but the datasheet for the MAX551 hints that best performance is obtained with a -5V reference.

C13 and R42 allows the op-amp to drive the high capacitance load of the sample and hold circuits without DC error or instability. D7 is there to protect the demultiplexer chip, U14, from any spurious negative voltages that may occur on power up.

Notice, that the op-amps and reference have separate grounds to the digital parts of the circuit. They have a different symbol on the circuit diagram like an upside down triangle. This is called 'analogue ground'. It is at the same potential as digital ground and both are connected at the star point within your system's power supply. The theory is that any current spikes on the digital ground do not manifest themselves as voltage fluctuations on the sensitive analogue ground.

The DAC's output is constantly varying. All six CV outputs, which are controlled by a stream of 12-bit data from the PIC, are represented by this fluctuating output. Each output has its own time slot and this gives rise to a waveform that has six distinct sections that continuously repeat, once every 4000th every second.

The demultiplexer based around U14 will direct each of these six outputs to its own output section. U14 is like an electrically controlled rotary switch. The PIC controls this switch via the level shifting chip, U15. The demultiplexer needs a 15V logic signal whilst the PIC only provides +5V. U15 is a one chip solution to this and converts the low level logic from the PIC into the high level logic needed to drive the 4051. The switching is tied in directly to match the output of the DAC so that the correct order of the time slotted output goes to the correct destination. The PIC also only enables U14 in such a way so as to allow the output of U8 to settle accurately before allowing it through to the next stage.

Each output section is called a 'sample and hold', although to be strict the demultiplexer also forms part of the sample and hold. The capacitor in each S/H holds or stores the voltage that is briefly connected to it. The op-amp that is connected to it, allows this voltage to be 'sniffed' without effecting the actual value. The op-amps are connected as voltage followers or buffers. They have gain of 1. Thus, the sampled voltage on the hold capacitors can be found at the output of each op-amp. Note, that pitch CV and pitch bend use low offset FET op-amps, U12, for accurate pitch control.

Note that not all of the eight outputs from the demultiplexor are connected to S/H circuits. The PIC only processes six midi controllers so the other two outputs are unused.

The pitch and pitch bend CV are processed further by the midiDAC. This circuitry is seen on page two of the schematics.

The pitch CV is sent to the slide circuit. This circuit is based heavily on the slide circuit from the TB303, and, of course, the Oakley 3031. When the slide is not enabled, the first portion of the analogue switch, U5, is off. The pitch CV is then passed through the slide pot straight to the op-amp buffer, U4 (pins 1, 2, 3). The resistance of the slide pot has no effect on the CV because the input impedance of the buffer is very, very high. The second portion of U5 is on, and the capacitor, C2 is charged up to the CV voltage. Slide is activated, either by the PIC via the SLD logic line, or manually via the 'SLID' header being shorted by the SLIDE switch. This then causes the two sections of U5 swap states. The pitch CV now has to charge C2, via the slide pot, every time the CV changes. The higher the resistance of the slide pot, the longer it takes to charge up or down.

The slide signal from the PIC also drives the 'legato' LED via U6. The LED is connected to a 2 pin header on the PCB, labelled 'LEG'.

The pitch bend CV varies from 0 to 10V depending on the status of the pitch bend controller. For normal use, we require the pitch bend to go from -5V to +5V, with 0V representing the pitch bend wheel centralised. To do this we must subtract exactly 5V from our pitch bend CV signal.

This is done with a simple summing amplifier based around U2 (pins 5, 6, 7). This adds the -5V reference voltage to the pitch CV. Since the pitch CV is centralised at +5V, when we add these two voltages together, they cancel. However, a positive (upwards) bend produces a negative voltage so we must invert the summed output with another op-amp circuit. This is based around U4 (pins 5, 6,7) and features capacitive loading protection via R28 and C8. The output of this circuit goes to the Pitch bend output socket and the Pitch Bend depth pot.

The Pitch bend depth pot allows a fraction of the pitch bend CV to be added to the pitch CV. Thus wiggling the pitch bender will automatically control the pitch of any connected VCOs. The circuitry based around both halves of U1 add the pitch bend CV to the pitch CV and to allow fine tuning of the VCO pitch.

Note the use of 0.1% resistors in the summing circuit. If ordinary 5% resistors were used here, it is likely that the -5V and the +5V signals would not be exactly cancelled. This would result in a small error voltage, ie. non zero, at the pitch bend output.

Two forms of setting the initial pitch CV are provided. One is the TUNE pot mounted on the front of the panel. The other is INIT, which is a multiturn trimmer that will allow precise setting of the initial pitch CV, and thus aid centralising the TUNE pot's range. In this version of the midiDAC, the pot and trimmer take their end voltages from the +5V and -5V reference voltages. This should lead to greater stability of the CV output even if the power supplies change slightly.

There are 12 notes in one octave, and a jump of 1V must represent one octave when applied to a VCO. Thus, $1/12 = 0.083333V$ or 83.33mV per semitone step with a perfect DAC. There are 127 notes in the midi scale, so the highest voltage must be $127 \times 83.3mV = 10.58V$.

With a -5V reference the smallest step our DAC will increment is only 78.7mV, so we need to amplify up the pitch CV by around 1.06 to get the desired 83.3mV stepping. This is done in the first summing circuit. The V/OCT trimmer allows to fine tune this gain to match your midiDAC to your VCO's sensitivity.

The PIC generates the gate signal directly from on if its outputs. It actually an inverted gate to allow the main gate output to be generated by a single NPN transistor, Q2. The collector may be wired to either the +5V or the +15V rail depending on the size of the gate signal required. The GATE LED is connected to a 2 pin header on the PCB, labelled 'Gate'. Its driven by a spare gate within the inverter chip, U6. Note that if you use the suggested layout, the LED may be mounted straight into the board for a tidy appearance.

U11 provides the regulated +5V supply for the PIC and DAC. R54 and C16 provide power supply decoupling from the higher +15V rail. The four ferrites on the board, L1 to 4, act as high frequency suppression to remove any digital noise from the power supply. The level shifting chip, U15 and the demultiplexer, U14 also have their own decoupled and filtered supply. This is to prevent the fast switching pulses generated by U15 from affecting the power supplies in the modular. Any digital noise would be heard as audible whining from any audio output.

PIC Firmware Data Version 2.2

The PIC could in theory generate 8 output control 'voltages' when used with a single DAC and 8-channel demultiplexer. However, we only use six of them in this version of the midiDAC and tbDAC firmware:

<i>Output</i>	<i>CV generated</i>
1	Pitch CV
2	Modulation Wheel
3	Note on velocity
4	Pitch bender
5	Aftertouch
6	CC 100
7	Reserved
8	Reserved

The PIC also generates two digital type signals direct from its own ports. These are gate and slide. The former goes low when any note on is received on the selected midi channel and will go high when a note off, or key velocity zero, is received. It will briefly blip high in the case of 'legato mode' off if a second (or third, etc.) note is pressed whilst others are still held down.

The Slide output will go low if more than one note is active on the selected midi channel. The slide will go high if there are no overlapping notes.

For both logic outputs, it is expected that the PIC will drive NPN inverting stages. This is to protect the PIC from improper connections to the true slide and gate outputs. It also provides the facility to level shift upwards very easily.

A third logic output is also available that can drive a midi active LED which is unused in the midiDAC-3. This output goes low for 500mS if any valid midi data is present on the midi port.

Midi Channel selection

Midi channel is selected by four lines which must be either floating or be grounded. The simplest way to set midi channel is with a 4-way DIP switch which shorts the data line to ground. 0 is switch closed (ON) and 1 is switch open (OFF). Binary codes are being read pin 4 to pin 1. Pin 4 is MSB, pin 1 is LSB.

<i>Code</i>	<i>Midi Channel</i>
0000	1
0001	2
0010	3
0011	4
0100	5
0101	6
0110	7
0111	8
1000	9
1001	10
1010	11
1011	12
1100	13
1101	14
1110	15
1111	16

For example, to set midi channel 3, set the DIP switch to 0010. That is, from positions 1 to 4:

1- on, 2- off, 3- on, 4- on.

Gate Trigger Modes

The midiDAC allows the selection of two gate trigger modes via the ‘Legato mode’ switch. This is marked on the new PCB as ‘RE-TRIG’. You can connect a simple SPST switch to this or a simple jumper. The setting of this switch/jumper determines how the gate signal responds to overlapping notes. Closing this switch, or fitting the jumper, enables multiple gate triggering for legato playing. This is the re-trig option. The gate signal is taken briefly low at the start of a new note, even if the fingers haven’t left the keyboard from the previous note.

With the switch open, or leaving the position blank, the gate does not retrigger for overlapping notes. This is the classic analogue keyboard method and more suitable for those TB303 slides.

Legato Mode may also be enabled or disabled via the Legato Footswitch MIDI messages. If these messages are to be used, the Legato Mode switch on the tbDAC unit should remain in the off position.

midiDAC Implementation of MIDI Controllers

The following table summarises the MIDI controllers supported by the midiDAC firmware.

<i>Hex</i>	<i>Dec</i>	<i>Midi Controller Definition</i>	<i>Implementation on the midiDAC</i>
41h	65	Portamento (Slide)	On / Off Switches the portamento (slide) function
44h	68	Legato Footswitch	Controls the gate retrigger mode. 0 to 63 = off, 64 to 127 = on.
78h	120	All Sound Off	Silences all notes & clears accent/gate/slide.
79h	121	Reset All Controllers	Data byte = 0 for this controller. Centres Pitch Wheel and zeroes various controllers.
7Bh	123	All Notes Off	Data byte = 0 for this controller. Silences all notes & clears accent/gate/slide.
7Ch	124	Omni Mode Off	Data byte=0 for this controller. Unit responds only to selected MIDI channel.
7Dh	125	Omni Mode On	Data byte=0 for this controller.* Unit responds to any MIDI channel. Data byte=0 for this controller.*
7Eh	126	Poly Mode Off	All notes cleared*
7Fh	127	Poly Mode On	All notes cleared*

* In accordance with MMA specifications, all notes are cleared when these controller messages are received.

Note Priority

The midiDAC firmware uses last note priority. That is, it will assign the pitch CV to the last note to be held. However, all 'overlapped' notes are still retained in memory and are reactivated in order should the most recent notes to be held be released.

Firmware Bugs

As far as we know there are no known issues with the software in its current state. The design has been tested and used extensively and we have not found any problems. The midiDAC has proved very rugged and is very reliable. However, there was one report that auxiliary CV outputs were unstable when the selected midi channel was between 9 and 16 and when the midi buss was very busy. We were unable to reproduce this so it may have been poorly performing midi buss on the user's system. But it may have been that we were 'lucky' in not being able to replicate exactly the fault conditions. In any case, if you do notice **any** problems with the way the midiDAC handles midi data, please do let me know.

Copyright Notice

Please note: No permission is granted to copy in anyway, or alter, the PIC firmware provided on the tbDAC PIC. The PIC is copy protected and we will not tolerate any attempt at bypassing this protection. A lot of hard work has gone into the design of the firmware, please do not steal it from us. The firmware is not available separately, although pre-preprogrammed PICs may be supplied to interested parties wanting to develop midi-CV interfaces for their musical projects. Please contact me at Oakley Sound for more information.

Components

Most of the parts are easily available from your local parts stockist. I use Rapid Electronics, RS Components and Farnell, here in the UK. The midiDAC module was designed to be built mostly from parts obtainable from Oakley Modular and Rapid Electronics.

The pots are Spectrol 248 series pots with 1/4" shafts. These are high quality sealed conductive plastic potentiometers. Rapid, CPC and Farnell sell these parts in the UK. The pot brackets are especially made for us, and are only available from Oakley Sound Systems. Oakley Modular also sell the pots should you find it difficult to get them yourselves. It should be noted that the price of Spectrol pots have gone up significantly since Spectrol was acquired by Vishay. This is particularly true of the logarithmic taper pots of which the midiDAC uses one.

Many of the resistors are 1/4W 5% or better types. Although there are some 1% and 0.1% resistors listed. I would generally recommend 1% metal film types throughout except where 0.1% are specified. The 10K 0.1% resistors are sold by Rapid at pt. number: 63-1448.

The most excellent MAX551ACPA is available from Maxim direct, although they may have minimum order quantities in your country. Because of this, the part is available through Oakley Modular for a very reasonable price.

All the electrolytic capacitors should be radially mounted. The working voltage for the 1uF and 2.2uF capacitors should be either 50V or 63V. The other values should have a working voltage of 25V or 35V to keep the physical size down.

The pitch spacing of the polyester capacitors is 5mm (0.2"). I use metalised polyester film types. These come in little plastic boxes with legs that stick out of the bottom. Try to get ones with operating voltages of 63V or 100V.

C2 is specified as a 1.5uF, 63V (or 50V) polyester capacitor. You can use a 2.2uF, 63V low leakage electrolytic or tantalum bead here if you are having problems finding a polyester big enough. If you do fit the electrolytic or tantalum capacitor you must make sure that the negative lead goes to the pad nearest the bottom of the board.

The PCB is another Oakley board to feature spacing to incorporate axial multilayer ceramics for the power supply decoupling. These are good components with an excellent performance. Various types exist but I tend to use the X7R types from Rapid, pt. number: 08-0240.

The low capacitance (values in pF) ceramics have 5mm (0.2") lead spacing. For these ceramic capacitors use low-K types. These are the better quality ones with higher stability and lower noise. They are sometimes described as NP0 or C0G types. You can chose either radial multilayer types, or ordinary plate types. RS-Components and Farnell sell the former, whilst plate types can be bought from pretty much anywhere.

L1 to L4 are leaded ferrite beads. These are little axial components that look like little blackened resistors. They are available from most of the mail order suppliers. Find them in the EMC or Inductor section of the catalogues. Farnell sell them as part number: 108-267.

The midi channel selection is performed by a 4 way DIP switch. These are available in many different types, but get the ones with 0.3" spacing between the rows. This is the most common type anyway. Avoid the piano key style ones, since they can be very confusing... er, which way is on? Fit the switches so that switch one is towards the bottom of the board. LSB is then switch one.

The BC550 devices are discrete low noise transistors. You can replace them with BC549 or BC548 types respectively, although the voltage rating of the BC550 and BC560 is higher. Quite often you see an A, B or C suffix used, eg. BC549C. This letter depicts the gain or grade of the transistor (actually hfe of the device). The midiDAC is designed to work with any grade device.

Some of the op-amps are not your ordinary TL072 type. There is a good reason to use the ones specified. The OPA2277PA is a low offset bipolar op-amp. It may be substituted with a LT1013. Both these parts will give less pitch drift. The AD712JN is a low offset FET op-amp. This has a high impedance, low bias current and high speed and is well suited for the DAC

output amplifier. The LF412 is a fairly standard dual FET op-amp with a good performance in sample and hold applications.

The HEF4104BP is a four channel low to high level shifter. Its available from Farnell and also from Oakley Modular.

The REF02 is a 5V reference. Get the cheapest one in DIL form on offer.

All but one of the ICs are dual in line (DIL or DIP) packages. These are generally, but not always, suffixed with a CP or a CN in their part numbers. For example; TL074CN. Do not use SMD, SM or surface mount packages.

One of the ICs is a three pin TO92 style package. This is the 78L05 which is a 5V 100mA regulator chip.

The multiturn trimmers are the ones that have the adjustment on the top of the box. Spectrol and Bourns make these. Some types are 22 turns, while others are 25 turns. Either will do. They should have three pins that are in a line at 0.1" pitch. Don't chose the 10-turn ones with the adjustment on the end, they won't fit on the PCB.

The crystal is a 4MHz type. Low profile ones are now available and these can be used if you can get them. The usual types will fit no problem.

The LEDs should be a 5mm diameter LED types. I tend to recommend bipolar LEDs, available from Rapid, so I don't have to remember which way around to put them into the board. However, I notice that Rapid seem only to selling red and green bipolar LEDs now. You can chose any colour LED you wish; I have used two green ones when I made the midiDAC shown in the pictures in this User Guide. The LED clips I get from Maplin in the UK. They have a built in lens and hold the LED firmly to the front panel. For green LEDs, it is best to get green lens, for yellow ones get a yellow lens.

The recommended switch is a normal SPDT toggle type. I use ones with a flat toggle to match with the MOTM modules. Apem and C&K make good ones. Farnell part number: 1082301. There will be more detail on how to wire the switch to the board later on in this document.

The PCB has been laid out to accept 0.1" headers for all the interconnects except for the power supply. Pin 1 is depicted by the square pin. The three way 0.1" header is for use with the Dizzy normalisation scheme. See the Dizzy User Guide for more information.

Input and output sockets are not board mounted. You can choose whichever type of sockets you wish. I use the excellent Switchcraft 112 as used on the Moog and MOTM modulars. At least one of the sockets must have normalising lugs. The Switchcraft 112 types have normalising lugs as standard.

Finally, if you make a change that makes the circuit better, do tell the 'Oakley-synths' mailing list or myself directly. Any updates are added to the current user guide as quick as possible.

UK builders should know that there is a 'Oakley Preferred Parts List' online which is updated periodically by myself. This can be found at www.oakleysound.com/parts.pdf.

Parts List

A quick note on European part descriptions. To prevent loss of the small '.' as the decimal point, a convention of inserting the unit in its place is used. eg. 4R7 is a 4.7 ohm, 4K7 is a 4700 ohm resistor, 6n8 is a 6.8 nF capacitor.

Resistors

All values are 5% carbon or metal film $\frac{1}{4}$ W or better except those listed as 1% or 0.1%. These must be 1% metal film and 0.1% metal film respectively.

100K	R16, R18
100R	R54, R56
10K	R30, R29, R25, R37
10K, 1%	R21, R7, R4, R22
10K, 0.1%	R45, R24, R26, R40
11K	R17
1K	R10, R53, R42, R44, R48, R34, R49, R47, R50
220R	R38, R52, R14
22K, 1%	R15, R9
22R	R55
2K2	R51, R11
33K, 1%	R19
390K, 1%	R5
3K3	R27
47K	R1, R6, R13, R36
4K7	R32, R31, R8, R23, R46, R43, R41, R39
680R	R3, R2, R12
75R	R28, R20

For +15V gate output: Make R33 a 10K resistor and omit R35.

For +5V gate output (recommended): Make R35 a 10K resistor and omit R33

Trimmers

2K Multiturn cermet	V/OCT
100K Multiturn cermet	INIT

Pots

50K linear Spectrol 248	TUNE, BEND
100K log Spectrol 248	SLIDE

Capacitors

100nF axial multilayer ceramic	C23, C11, C36, C32, C3, C30, C15, C4, C6, C5, C12, C21, C20
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10nF 100V polyester film	C1, C31, C27, C28, C34, C29, C33
18pF low-K ceramic plate	C25, C26, C19
1uF, 63V electrolytic	C10
1u5, 63V polyester	C2*
22uF, 25V electrolytic	C35
2u2, 63V electrolytic	C9, C22, C14, C24, C17, C18
33pF low-K ceramic plate	C13, C8, C7
47uF, 25V electrolytic	C16

* This maybe substituted with a 2u2, 63V electrolytic. See text for more details.

Discrete Semiconductors

1N4001 silicon diode	D9, D10, D8, D3
1N4148 signal diode	D5, D6
BAT42 schottky diode	D7, D1, D2, D4
BC550 small signal NPN transistor	Q2, Q1
5mm LED of any colour	GATE, LEG

Integrated Circuits

16F628-04 midiDAC PIC	U10
CD4051B 1-8 mpx	U14
CD4066B analogue switch	U5
HEF4104BP level shifter	U15
6N137 optocoupler	U7
74HC04 Hex invertor	U6
78L05 +5V regulator	U11
AD712 Dual FET op-amp	U8
LF412 Dual FET op-amp	U12
MAX551ACPA 12-bit DAC	U9
OPA2277	U4, U1, U2
REF-02 Precision 5V reference	U3
TL084 Quad FET op-amp	U13

Connectors

4-way Molex 0.156" header	1 off (PSU)
4-way 0.1" header and socket	2 off (CN1, CN2)
3-way 0.1" header and socket	2 off (midi thru and Dizzy Bus)
2-way 0.1" header and socket	1 off (midi in)

Miscellaneous

4MHz Crystal (parallel resonant)	X1
FERRITE	L1, L2, L3, L4
LED clips	Two off, colours to suit choice of LEDs
Toggle switches	Two off, one for Trigger and one for Slide
4-way DIP switch	One off

Knobs	Three off
1/4" sockets	Eight off
5-pin midi sockets	Two off

You may well want to use sockets for the ICs. I would recommend low profile turned pin types as these are the most reliable. You need eight 8-pin DIL, three 14-pin DIL, two 16-pin DIL, and one 18-pin DIL.

Building the MidiDAC

Warning:

Oakley Modular PCBs are supplied with a RoHS compliant Ni/Au finish. This is a high quality finish but does possess slightly different soldering characteristics to the traditional lead based HASL finish. Handle the boards with care, and avoid touching the Ni/Au plating since this can cause premature tarnishing of the finish. Shelf life is hard to predict but Oakley Modular recommend soldering in all the components less than one year from when you receive your board.

Neither I nor Oakley Modular are responsible for any accidents caused whilst working on these boards. It is up to you to use your board responsibly and sensibly.

Occasionally people have not been able to get their Oakley projects to work first time. Some times the boards will end up back with me so that I can get them to work. The most common error with most of these was parts inserted into the wrong holes. Please double check every part before you solder any part into place. Desoldering and removing parts on a double sided board is a skill that takes a while to master properly.

If you have put a component in the wrong place, then the best thing to do is to snip the component's lead off at the board surface. Then using the soldering iron and a small screwdriver prize the remaining bit of the leg out of the hole. Then use wick or a good solder pump to remove the solder from the hole. Filling the hole with fresh solder will actually make the hole easier to suck clean!

Sometimes people like to substitute parts in place of my own recommendations. Feel free to do this, but remember that there is normally a good reason why I have selected that particular part. If you do find that, say changing an op-amp with another one, makes an improvement, please do let me know either via the Oakley-Synths list or directly to me.

All resistors should be flat against the board surface before soldering. It is a good idea to use a 'lead bender' to preform the leads before putting them into their places. I use my fingers to do this job, but there are special tools available too. Once the part is in its holes, bend the leads that stick out the bottom outwards to hold the part in place. This is called 'cinching'. Solder from the bottom of the board, applying the solder so that the hole is filled with enough to spare to make a small cone around the wire lead. Don't put too much solder on, and don't put

too little on either. Clip the leads off with a pair of side cutters, trim level with the top of the little cone of solder.

Once all the resistors have been soldered, check them ALL again. Make sure they are all soldered and make sure the right values are in the right place.

The diodes can be treated much like resistors. However, they must go in the right way. The cathode is marked with a band on the body of the device. This must align with the vertical band on the board. In other words the point of the triangular bit points *towards* the cathode of the diode. When all the diodes are in place, double check all are pointing the right way.

The axial ceramics and ferrites can be treated like resistors. Both can be fitted anyway round.

The polyester film capacitors are like little blue or yellow boxes. Push the part into place up to the board's surface. Little lugs on the underside of the capacitor will leave enough of an air gap for the water wash to work. Cinch and solder the leads as you would resistors.

The plate ceramic capacitors are strange flat plates made from pot. Be careful with these and make sure you have bought the ones with 0.2" lead spacing. Forcing the smaller 0.1" ones into these larger pads will break them. Another thing to watch out for is the identification markings on these capacitors. For example n47 is actually 470pF.

The smaller electrolytic capacitors are very often supplied with 0.1" lead spacing. My hole spacing is 0.2". This means that the underside of these radial capacitors will not go flat onto the board. This is deliberate, so don't force the part in too hard. The capacitors will be happy at around 0.2" above the board, with the legs slightly splayed. Sometimes you will get electrolytic capacitors supplied with their legs preformed for 0.2" (5mm) insertion. This is fine, just push them in until they stop. Cinch and solder as before. Make sure you get them in the right way. Electrolytic capacitors are polarised, and may explode if put in the wrong way. No joke. Oddly, the PCB legend marks the positive side with a '+', although most capacitors have the '-' marked with a stripe. Obviously, the side marked with a '-' must go in the opposite hole to the one marked with the '+' sign. Most capacitors usually have a long lead to depict the positive end as well.

The transistors are all in the same type of packaging and therefore look the same. Only the numbers on the side will allow you to tell them apart. Match the flat side of the device with that shown on the PCB legend. Push the transistor into place but don't push too far. Leave about 0.2" (5mm) of the leads visible underneath the body of transistor. Turn the board over and cinch the two outer leads on the flip side, you can leave the middle one alone. Now solder the middle pin first, then the other two once the middle one has cooled solid.

Sometimes transistors come with the middle leg preformed away from the other two. This is all right, the part will still fit into the board. However, if I get these parts, I tend to 'straighten' the legs out by squashing gently all the three of them flat with a pair of pliers. The flat surface of the pliers parallel to the flat side of the transistor.

For the 78L05 regulator IC, mount this as you would a transistor.

For the trimmers; look very carefully at each one before soldering them into place, they are very difficult to remove if you put them in the wrong place. If your multiturn pot is marked as 104, then this is a 100 000 ohm or 100K pot. 202 is a 2K pot. These multiturn pots can go in any way around.

I would make the board in the following order: resistors, IC sockets, small non-polar capacitors, transistors, electrolytic capacitors and headers. Then the final water wash. You can now fit the trimmers, crystal and DIP switch to the board with no-clean or ordinary 'ersin' flux solder. Do not fit the pots or the LEDs at this stage. The mounting of the pots requires special attention. See the next section for more details.

Mounting the Pots

The first thing to do is to check your pot values. Spectrol do not make it that easy to spot pot values. Your pot kit should contain:

Value	Marked as	Quantity
50K linear	M248 50K M	2 off
100K log	248-J-100K	1 off

Fit the pot brackets to the pots by the nuts supplied with the pots. You should have two nuts and one washer per pot. Fit only one nut at this stage to hold the pot to the pot bracket. Make sure the pot sits more or less centrally in the pot bracket with legs pointing downwards. Tighten the nut up carefully being careful not to dislodge the pot position. I use a small pair of pliers to tighten the nut. Do not over tighten.

Now, doing one pot at a time, fit each pot and bracket into the appropriate holes in the PCB. Solder two of the pins attached to the pot bracket. Leave the other two pins and the three pins of the pot itself. Now check if the pot and bracket is lying true. That is, all four pins are through the board, and the bracket should be flat against the board's surface. If it is not, simply reheat one of the bracket's soldered pads to allow you to move the pot into the correct position. Don't leave your iron in contact with the pad for too long, this will lift the pad and the bracket will get hot. When you are happy with the location, you can solder the other two pins of the bracket and then the pot's pins. Do this for all three pots and snip off any excess wire from the pot's pins at this point.

You can now present the front panel up to the completed board. Although, I usually fit the sockets at this point, and wire up the ground tags first. After this is done, I then mount the PCB to the front panel. You need to add the washer between the panel and the nut. Again, do not over tighten and be careful not to scratch your panel.

The pots shafts of these three pots will not need cutting to size. They are already at the correct length.

The Spectrol pots are lubricated with a light clear grease. This sometimes is visible along the screw thread of the pot body. Try not to touch the grease as it consequently gets onto your panel and PCB. It can be difficult to get off, although it can be removed with a little isopropyl alcohol on cotton wool bud.

Connections

How you connect your midiDAC very much depends on where you are going to use the midiDAC. You may already have an idea of how you are going to connect your midiDAC to your chosen system. For those building the standard Oakley midiDAC modular panel I will give the wiring instructions in detail.

The suggested layout uses eight sockets, and wiring them up is straightforward enough. Use multistrand hook up wire to connect each socket's signal lug to the relevant pad on the PCB. Keep your wires short but not too short and use as many different colour wires as you can. There is no need to use screened cable for such short runs.

If you have used Switchcraft 112 sockets you will see that they have three connections. One is the earth lug or ground tag. The second is the signal tag which will be connected to the tip of the jack plug when it is inserted. The third tag is the normalised tag, or NC (normally closed) lug. The NC lug is internally connected to the signal tag when a jack is not connected. This connection is automatically broken when you insert a jack. The midiDAC uses only the signal lugs on each connector. The other two lugs are not used at all in the suggested layout.

The PCB has been laid out to accommodate 0.1" headers for all interconnects. This is very useful for taking the board in and out for servicing. However, for a panel fitting into a modular synth, there is no reason why you can't solder wires directly into the holes.

Socket name	Header	Pin
Pitch	CN1	1
Velocity	CN1	2
Bender	CN2	4
Modulation	CN2	2
Aftertouch	CN2	1
CC	CN2	3
Gate	CN1	3
Slide	CN1	4

The earth lugs of each socket are left floating as a solid ground to the module is already provided in the form of the power supply ground lead(s). This means that no earth loops will occur because of inserted patch leads. However, depending on your own system, it may be necessary to connect each output jack's ground tag to the AGND on the input power connector on the PCB. You can connect all the ground lugs together with a piece of uninsulated wire, and have one piece of insulated wire going back to the AGND pin. But remember a modular panel will probably be metal, and may well be earthed through the panel

housing. Your best bet is to leave the lugs unconnected at first, and only connect them to ground if you get problems. My ready made units have the grounding lugs unconnected.

All other Oakley modules have two grounds, one for the chassis and jack screening, the other for the power supply to the module. The midiDAC couldn't use this method with just a four way plug. Here, we have AGND and DGND, both must go back to the power supply separately. It is preferential to use a separate 4-way power lead to the midiDAC that comes straight from the power supply and not via any other module.

The ideal modular would have three grounds, a chassis or safety ground, a clean power supply ground (AGND) and a dirty power supply ground (DGND). To remain compatible with the MOTM system, I have stuck with just two grounds.

If you are fitting your midiDAC into a single box with some other analogue synth circuitry, the connect the two midiDAC grounds to the central power supply star point. You do not need any further connections to ground from or to the midiDAC.

The two LEDs should be able to be wired directly to the board without using additional lengths of hook up wire. Pin 1, the square pad, should go to the anode of the LED. And pin 2 to the cathode. If you have used bipolar LEDs you can wire these in any way around they'll still work fine. You will have to bend the legs of the LED towards to board. This should be done close to the body of the LED and be done carefully so as not to break the resin casing of the device. Use a pair of fine nosed pliers to do the job. A LED clip should be used to secure the LED to the panel. The Cliplite range from Maplin, and others, are perfect for this job and offer a smart finish. Alternatively the integrated Lumex parts come with their own casing and but should still fit into the PCB directly.

The two switches will now be wired to the panel. These require short lengths of wire to connect them to the board. A standard SPDT switch has three solder tags. You will need to connect the two pads on the board to the top two tags on the relevant switch. The lower tag on each switch is left unconnected. It doesn't matter which wire goes to which tag, the main thing is that each switch gets the correct pair of wires.

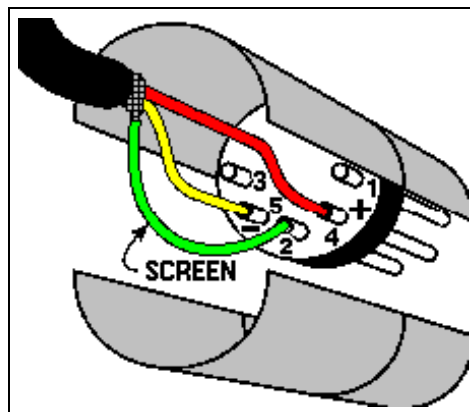
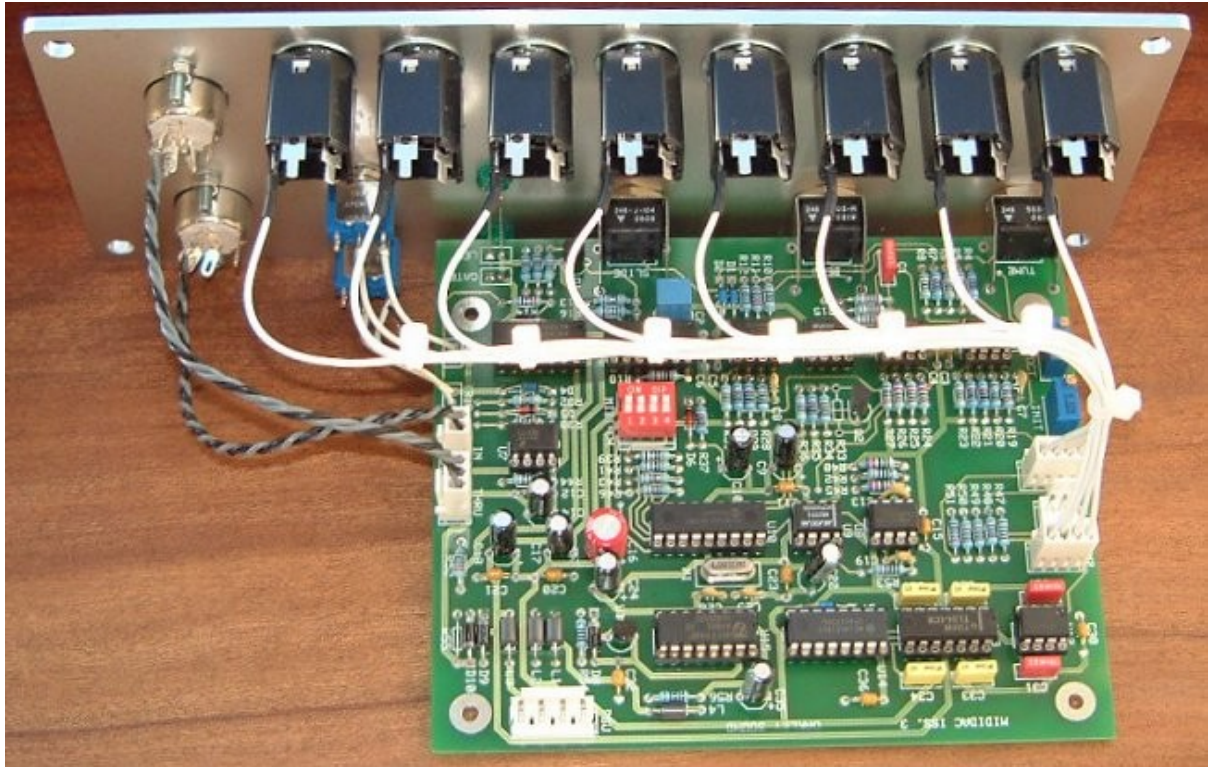


Figure 1. An internal view of the standard MIDI plug. Picture courtesy of Philip Rees Ltd.

The MIDI sockets require a mention. If you get the connection around the wrong way, a lot of confusion will result. For the MIDI IN connector: pin 1 on the PCB goes to pin 5 on the 5-pin

DIN. Note that pin 5 is marked on the socket and is NOT the fifth pin on the socket. Pin 2 on the PCB goes to pin 4 on the DIN plug. For the MIDI OUT connector: pin 1 on the PCB goes to pin 5 on the DIN plug, pin 2 on the PCB goes to pin 2 of the DIN plug, pin 3 on the PCB goes to pin 4 on the DIN plug. On the PCB pin 1 is always depicted by a square pad. If you have a problem with the midiDAC, chances are that you have wired up the midi socket incorrectly.



The rear view of a recently made midiDAC-3. This one has been built onto a natural finish Schaeffer front panel. The sockets are Switchcraft 112APC with a small amount of heatshrink acting as a strain relief for the connected wire. No wired ground connection is made to the output sockets.

The Front Panel

On the website I have included a FPD database of the suggested 2U front panel layouts in both standard black and a nice new look natural finish. Actual panels can be obtained from Schaeffer-Apparatebau of Berlin, Germany. The cost is about £30 for the panel and slightly more for the natural finish thanks to the additional colours used in the legending. VAT and the postage is extra, so it usually helps to order a few panels at the same time.

All you need to do is e-mail the fpd file to Schaeffer in Germany, or Frontpanel Express in the US, and they do the rest. You can also use the Frontplatten Designer program's own online ordering procedure which also works very well.

The panel itself is made from 3mm thick black anodised aluminium. The fpd panel can be edited, including changing the colour, with the Frontplatten Designer. The program available on the Schaeffer web site but it should be noted that the program is for Windows only.

Trimmers

There are two trimmers on the midiDAC PCB. Both of them are designed to allow you to make the midiDAC respond correctly to the rest of the modular system. If you already have a perfectly tuned and calibrated system, it is best to trim the midiDAC to suit your system rather than the other way around.

1. **V/OCT.** This controls the scaling of the pitch CV output. That is, how much the VCO pitch will change with every note increment on the controlling keyboard.

If you already have a calibrated set of VCOs with your current system it is best to set the midiDAC's V/OCT to match your existing set up. Therefore, connect the midiDAC to one of your VCOs and adjust V/OCT until you get perfect tuning.

Remember altering V/OCT will affect all notes on the keyboard, so you need to be looking at getting an octave interval between the notes rather than setting absolute pitch of one note. The INIT trimmer can be used for setting absolute frequency, see later for more details.

If you do not have an existing system and the midiDAC is your first module, a perfectly calibrated midiDAC will then ensure that the rest of the system will be true. Connect the midiDAC to a keyboard or computer midi interface and power up. Set the TUNE pot to its middle position. To ensure that the pot is perfectly centralised, measure the voltage on the wiper of the pot with respect to ground. Fine tune the pot until the voltage is between +20mV and -20mV. You may find it easier to measure this voltage at the left hand end of R5.

Ground can be obtained anywhere connected to 0V. The mid point of C20 and C21 is a handy location.

Now play the highest midi note on your keyboard. Measure the voltage on pin 1 of U1. Adjust V/OCT until you get 10.58V. This will give you a nominal 1V/octave response.

2. **INIT.** This adjusts the offset applied to the pitch CV. Adjust this to tune the pitch of your master VCO. Set the TUNE pot on the front panel to the centre position before you start the adjustment of the INIT trimmer. The position of this trimmer will very much depend on your VCO setup and there is no specific procedure to set this. Simply adjust INIT until you are happy that the VCOs in your modular can be transposed by the keyboard over your chosen musical range.

Final Comments

If you have any problems with the module, an excellent source of support is the Oakley-Synths Group that can be found at <http://launch.groups.yahoo.com/group/oakley-synths/>

If you can't get your project to work, then Oakley Sound Systems are able to offer a 'get you working' service. If you wish to take up this service please e-mail me, Tony Allgood, at my contact e-mail address found on the website. I can service either fully populated PCBs or whole modules. You will be charged for all postage costs, any parts used and my time at 20GBP per hour. Most faults can be found and fixed within one hour, and I normally return modules within a week. The minimum charge is 20GBP plus return postage costs.

Your comments and questions are important to both Oakley Sound and Oakley Modular. In the first instance, please use the Oakley Synths Group where a wealth of experience resides! Please do not contact me or Oakley Modular directly with questions about sourcing components or general fault finding.

Last but not least, can I say a big thank you to all of you who helped and inspired me. Special thanks go to Trevor Page who has written the firmware that makes the midiDAC actually work. Thanks also to all those nice people on the Oakley-Synths and Synth-diy mailing lists.

Tony Allgood

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Errors may have occurred in the preparation of this document. Please forward any errors found to me so I can correct them.

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