

Oakley Sound Systems

tbDAC issue 2.2

midi-CV Convertor

User's Guide

Version 1.2

July 2005

Tony Allgood B.Eng PGCE
Oakley Sound Systems
PENRITH
CA10 1HR
United Kingdom

Important Note

This is the User Guide is for the tbDAC issue 2 revision 2. If your board does not say “TBDAC2REV2” at the bottom left of the board, then this is the wrong User Guide for your board. Contact us to get the correct version.

Introduction

The tbDAC-2.2 is a high specification single channel midi to analogue convertor designed primarily for the Oakley 3031, but can be used for many other analogue V/OCT synthesisers. This project is a joint development between the author and Trevor Page. Trevor wrote the firmware for the processor, a **PIC16F628** running at **4 MHz** and designed the layout of the printed circuit board (PCB). The PIC used in this project is different to the original PIC used in the Oakley midiDAC and issue one tbDAC.

The tbDAC-2.2 features five control outputs:

Gate: +12V (or +15V) on, 0V off

Pitch CV: 127 steps of 12 bit accurate pitch voltage conforming to 0.8V/octave (1V/octave).

Pitch bend: This provides a voltage that is proportional to the pitch bend wheel/lever's position. The output is zero when the wheel is centralised, and goes positive for increases in pitch. The maximum output swing is +/- 1.3V. It can be trimmed to less than this if required.

Velocity: 0 to 8.5V proportional to midi note on velocity. This is used in the TB3030 and 3031 to control accent, slide and filter cut-off if selected.

Mod wheel: 0 to 8.5V proportional to the modulation wheel's position. You can control filter cut-off with this CV.

Slide: This goes to +12V (+15V) when any notes are played in legato fashion. That is when the old note is still being held as the new one is played. This output can drive the 3031's slide input directly.

The new design also features a high speed midi thru port.

The tbDAC-2.2 is essentially the same design as the midiDAC3, but differs in a few important aspects:

1. It is designed to run off +/-12V rails and produces 0.8V/octave pitch CV. It will produce 1V/octave if the power rails are +/-15V. This will be explained in more detail later.

2. The circuitry is simplified. The midiDAC3 features a slide circuit which is not needed for the TB3030/1 since the TB3030/1 already has one. Some of the more 'exotic' midi controllers

are not featured. There is no aftertouch or CC#100. These would not normally be used in the TB3030/1.

3. The board is a lot smaller. It is therefore quicker and easier to build.

The second issue tbDAC is similar in circuit topology to the old issue one board. However, some important changes have been made. The new board is smaller and is very compact, containing a lot of circuitry in a small space. We have not used any surface mount (SMD) components to keep the board easy to make and simple to fix if it goes wrong at some point in the future.

The DAC is now a MAX551ACPA. These are about the same price as the old 7545, but are more robust. Because they are serially accessed they are also smaller. The new DAC is in an 8-pin DIL package.

The new issue also features its own onboard reference voltage for excellent tuning stability.

The midi thru circuit has been changed completely. The old circuit, although it did work, was very prone to data skew errors if the opto isolator was a particularly poor specimen. The new circuit is blisteringly fast.

The board now features two LEDs. One of these is a MIDI receive light and works much as any other MIDI activity light on other rack mounted equipment. The second LED, is a simple fault finding one, and simply shows the state of the midi input. Its ideal for testing your midi connections (the most common wiring fault with builders of the original tbDAC) and whether the opto isolator has a problem.

The second revision of the issue 2 board is slightly different to the first revision. The new boards use a 5V reference as opposed to 8V to ensure better DAC linearity. Also, the pad holes sizes are made larger to make it easier to construct. The boards are now made in the UK and are of similar high quality to other Oakley boards.

Power Requirements

The module normally requires a split supply of +/-12V at around 25mA each rail. This comes from the two pads on the TB3030/1 marked as **+12V** and **-12V**.

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 tbDAC. They must be both connected to the power supply's star point or common ground bus. On the TB3030/1's PCB, this is the output pad marked as **GND**. Both wires will be connected to this one pad.

This next bit is important to understand if you are intending to use the tbDAC as a standalone midi-CV convertor and NOT as the sole controller for the TB3030/1.

The unit may be run off +/-15V rails. The unit will perform identically, except for one key difference. The output of the pitch CV **may** now be scaled to 1V/octave with small changes to a few of the resistor values.

Let me explain this further. To get 127 notes from a 1V/octave source, you need a maximum of 10.6V from your keyboard CV output. That is 127 notes of 83.3mV each. As you go up the keyboard each new note adds 83.3mV on to the last value. This cannot be reliably generated from an op-amp powered from +/-12V. But it can from +/-15V. By setting the pitch CV to follow 0.8V/octave we can still get all 127 notes from the midi keyboard even from a +/-12V supply. This is because we only now need a maximum voltage of 8.5V. Each new higher note only produces an increment of 67mV. And this is no problem to the TB3030/1 which can easily be made to accept this unusual standard and still play perfectly in tune. It requires just one resistor change on the TB3030/1.

Now it is possible to make the output 1V/octave if it could be made to go from -5.3V to +5.3V. A supply voltage of +/-12V could do this easily. However, the input of the TB3030/1 is not able to cope with any negative voltages. So without a big change to the TB3030/1 itself, the best option was to alter the pitch scaling to 0.8V/octave.

“But I want to use the tbDAC to drive *either* the TB3030/1 *or* another analogue synth!”

Sorry this can't be done, unless you change the analogue synth pitch scaling to 0.8V/oct too, or you power the tbDAC separately off +/-15V supplies. In this situation you are probably better off building the midiDAC in a separate case with its own power supply.

“But I want to build a TB3030/1 with midi. What does this all mean to me?”

Nothing. Just follow the instructions in this User guide and you will have your TB3030/1 under midi control in four hours.

Other Features

There is a note stack within the firmware to allow the tbDAC-2.2 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.

Note retriggering is 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 useful particularly when trying to emulate the TB303's slide function. Here a new note slides into another without retriggering the gate. So as the note slides, the volume of the note drops away as the pitch rises or falls.

'Retriggering' allows the gate to drop momentarily when any new note 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 if you are using the TB3030/1 as a normal keyboard synth.

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.

The tbDAC features a built in high speed midi THRU port. This essentially produces a copy of the midi input signal which can be then fed to another midi unit.

Circuit Description

The midi data is electrically isolated by U3, a high speed logic output opto-coupler. The output of U3 is pulled up via R8 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. U4 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 U4 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. U4 is also used to drive an LED. This LED will flicker as midi data is received. It has no real use in a finished instrument, but is dead useful if you are fault finding. I would normally fit this LED on the board. Seeing it gently flashing reassures me that I have not wired up the midi connector the wrong way around.

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 tbDAC 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, U11. 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 (processed on the 3031) and pitch bend (processed on the tbDAC) 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 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, D1. This generates a stable 5.0V at its output.

A multiplying DAC will invert the reference signal applied at pin 7. So to get a positive output from our DAC, we have invert the 5V reference with U9. This is a precision op-amp, configured as an inverting amplifier to produce the required -5V. V/OCT is a trimmer which allows fine tuning of the reference voltage to suit your own needs. In theory it would set so that the reference voltage is exactly -5.01V to give us exactly 0.8V/octave from the keyboard CV output. In practice, setting it to 5.0V +/-50mV is perfectly adequate since we can trim the V/octave scaling from the TB3031.

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 U8A. It needs to be accurate, have low drift over time and be fast settling. I have chosen an AD712 by Analog Devices. C26 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 to give our maximum voltage of 8.5V. This is done with the other half of U8B, which is configured as a non inverting amplifier of gain 1.69. Ideally, R39 and R38 should be 0.1% tolerance resistors. 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 8.5V by providing the DAC with a -8.5V reference. This is true, but the datasheet for the MAX551 hints that best performance is obtained with a nominal -5V reference.

C31 and R40 allow the op-amp to drive the high capacitance load of the sample and hold circuits without DC error or instability. D5 is there to protect the demultiplexer chip, U5, from any spurious negative voltages that may occur on power up.

If you have chosen to build your tbDAC to drive 1V/octave synthesisers, you need to note that two of the resistor values will need to be changed from the schematic. You require a full scale swing of 10.667V from the output of U8B. To do this you must make R39 a 6K8 resistor. This makes the gain of U8B up to two. The V/OCT trimmer must then be set to make the reference voltage 5.33V. You'll also need to change R20 to 33K, but more about this later.

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 four of the tbDAC's CV outputs, sent initially as a stream of 12-bit words from the PIC, are represented by the DAC's fluctuating output. Each output has its own time slot. This gives rise to a waveform that has eight distinct sections that continuously repeat, once every 4000th every second.

The demultiplexer based around U5 will direct each of these eight outputs to its own output section. U5 is like an electrically controlled rotary switch. The PIC controls this switch via the level shifting chip, U6. The demultiplexer needs a 15V logic signal whilst the PIC only provides +5V. U6 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 go to the correct destinations. The PIC also enables U5 so that the output of U8 has settled 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 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 demultiplexer are connected to S/H circuits. Although the PIC does indeed process other midi controllers, for the sake of simplicity, the tbDAC does not make them available. Some of these extra outputs are available on the midiDAC-3 though.

The odd arrangement around U12B (pins 5, 6, 7) allows the S/H op-amp to drive high capacitance loads without DC error or instability. It is unlikely to happen within the short wire runs between the tbDAC and the TB3030/1, but if you did have the two PCBs in different boxes, this circuit would keep the notes in tune. The same arrangement is repeated for the pitch bend output, U7A (pins 1, 2, 3).

The pitch bend CV from the S/H amplifier goes from 0V at bend low, to +8.5V (0.8V/oct) or 10.66V (1V/octave) at bend high. We need the pitch bend CV to go negative when 'bended' low, and positive when 'bended' high. We do this by adding the pitch bend CV to a fraction of the reference voltage. A simple op-amp summer based around U7B (pins 5, 6, 7) performs this task for us. The values of R22 and R20 are especially chosen so that at the mid point of the bender the output of U7B will be zero volts. Since the maximum full scale voltage is different for the tbDAC when in 1V/octave mode, a different value of R20 must be chosen in this case.

A trimmer, DEPTH, can be simply used to adjust the output level of the bender CV output. The pitch CV and bend CV are merged together to control the TB3030/1's pitch within the TB3030/1 itself.

U2 provides the regulated +5V supply for the PIC and DAC. R15 and C13 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, U6 and the demultiplexer, U5 also have their own decoupled and filtered supply. This is to prevent the fast switching pulses generated by U6 from affecting the power supplies for the TB3030/1. Any digital noise would be heard as audible whining from the TB3030/1's output.

midiDAC PIC Firmware Data Version 2.2

The PIC generates 8 output control voltages when used with a single DAC and 8-channel demultiplexer. However, we only use four of them:

<i>Output</i>	<i>CV generated</i>
1	Pitch CV
2	Modulation Wheel
3	Note on velocity
4	Pitch bender
5	Not used
6	Not used
7	Not used.
8	Not used.

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. 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 tbDAC allows the selection of two gate trigger modes via the 'Legato mode' switch. This is marked on the new PCB as 'RETRIG'. 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. Data byte = 0 for this controller.
79h	121	Reset All Controllers	Centres Pitch Wheel and zeroes various controllers. Data byte = 0 for this controller.
7Bh	123	All Notes Off	Silences all notes & clears accent/gate/slide. Data byte=0 for this controller.
7Ch	124	Omni Mode Off	Unit responds only to selected MIDI channel. Data byte=0 for this controller.*
7Dh	125	Omni Mode On	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 tbDAC 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.

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.

Components

Most of the parts are easily available from your local parts stockist. I use Maplin, RS-Ltd, Rapid Electronics and Farnell, here in the UK. In North America, companies like Mouser, Newark, Allied and Digikey are very popular. In Germany, Reichelt are very good. And in Sweden, try Elfa.

Many of the resistors are 1/4W 5% or better types. There are some 1% metal film resistors specified and you may want to use 0.1% metal films in these positions. I have used 1% 1/4W metal film throughout. Rapid Electronics sell these for a very reasonable price in batches of one hundreds.

There are four additional resistors shown on the parts list that are not shown in the tbDAC schematic. These four components are to be fitted onto the TB3030 PCB. If you have built your TB3030 a while ago, you may have to swap out the old ones. Just to be sure, please check that these parts on your TB3030 have been fitted correctly to work with the tbDAC. R23 must be a 82K, and R8 must be a 100K. Both of these should be 1/4W 1% metal films or better. R47 and 48 must be 10R 1/4W or 1/2W. If you are building the TB3031, then simply follow the instructions in the current 3031 User Guide.

The electrolytics should be over 16V, except where stated, and radially mounted. However, don't choose too high voltage either. The higher the working voltage the larger in size the capacitor. A 220V capacitor will be too big to fit on the board. 25V is a good value to go for the 22uF, and 50V or 63V for the 1uF.

The pitch spacing of the non-polar capacitors is 5mm (0.3"). I think polyester types are fine for all decoupling, coupling and filter uses. They are sometimes called normally called metalised polyester film and are available in many different working voltages. Use 63V or 100V. But remember the pitch spacing.

Some folks made the tbDAC and midiDAC with polypropylene capacitors in the S/H circuits. In my view this is not necessary since the refresh rate is so fast. Polyester capacitors will give you very good accuracy and no noticeable droop or ripple.

The low capacitance (values in pF) ceramics must have a pitch spacing of 5mm (0.2"). These can be ceramic plate type or the newer style multilayer ceramics in resin dipped cases. The multilayer types tend to be smaller, but do get the radial types and not the axial ones.

L-1 to L-4 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?

The crystal is a 4 MHz type. If you have a choice of types you need the parallel resonant sort in a HC49 casing. Low profile ones, case number: HC49/S, are now available and these can be used if you can get them. The usual types will fit no problem. However, it is a good idea to not allow the crystal's housing to lie up against the board's surface. By allowing 0.5mm or so between the PCB and the bottom of the crystal's case, you will allow water to wash away any flux, and prevent the case from touching the solder pads. You can buy special standoffs for this very purpose.

The two trimmers are multiturn (22 or 25 rotations) cermet types. These are the ones with all three pins in a line at 0.1" spacing. The best ones to get have the adjuster at the top. Bourns and Spectrol make these.

The op-amps in the tbDAC-2 can be chosen to suit your own needs. You have the choice. I have selected good quality opamps, but these come at a small price. However, prices vary from country to country. You may also have a few spare ones you would like to use. Trevor got his original midiDAC to work on just TL07x opamps. These will drift more than the ones I have listed, but they will be a quarter of the cost.

U9 can be any good quality bipolar single op-amp. I have chosen the OP177G, but you can use an OP07, OP77 and LF411.

All ICs are dual in line (DIL or DIP) packages except D1 and U2. These are generally, but not always, suffixed with a CP, CN or JN in their part numbers. For example; TL072CP. Do not use SMD, SM or surface mount packages.

D1 is a LM336-5, a 5V reference voltage chip. This should come in a TO92 package, ie. it will look like a small NPN transistor. They are available with different accuracies and temperature coefficients. Just get the cheapest one that your supplier sells. It will still have a perfectly good and accurate output for your needs. You can also use the Zetec ZRB500A01. This is not technically equivalent since is supplied in a plastic E-line package, but it still fits in nicely enough on the tbDAC and works very well. Rapid sell this part, pt. number: 82-2024.

U2 is a 78L05 voltage regulator. This should be bought in the standard TO92 package and not the 8 pin small outline (SO-8) one.

U6 is a 4104, this is a CMOS low to high level shifter and is part of the 4000 CMOS logic series. This part is available from Farnell and from the Oakley Sound website.

The two transistors are specified as BC549, but they can be any generic NPN that has the same pin out. For example, a BC550, BC548 and BC547 will all work perfectly well. You may see a letter after the device's name, usually A, B or C, for example BC549C. This is the hfe or grade of the transistor. Don't worry about this, the tbDAC can use any grade. I use the BC550 as the standard NPN transistor in most of the projects these days.

The DAC is the MAX551ACPA. As far as we know, no other manufacturer makes this IC apart from Maxim. This excellent part is available from the Oakley Sound webpage.

The PCB is laid out to accept 0.1" MTA or Molex headers for the two midi connections and the retrig switch if you fit it. You can, of course, wire directly to these pads which is probably preferable in a fixed installation.

The power connection is via a standard Oakley/MOTM 4-way 0.156" MTA or Molex header. However, please note that pin 3 is the second ground, and not panel earth. If you fitting the tbDAC into the TB3031, I recommend directly soldering the wires onto the board anyway. This offers better reliability in the long term.

You may want to add a 'trigger mode' switch. If so, this wires into the RETRIG pad. A simple SPST or SPDT switch will be fine for this application. Twist the two wires together to form a simple cable to reduce digital noise emissions. Alternatively, fit a two pin 0.1" header and use a shorting link jumper to set the trigger mode. Remember shorting the two pads within the RETRIG legend will enable re-triggering of the gate output on every new note.

There are two LEDs to indicate midi status and midi data, but they don't have to be fitted for correct operation of the convertor. The LEDs can be mounted directly to the board and will be helpful in tracking down faults should a problem occur. They should be ordinary 3mm types to fit on the board. They can be any colour, but I use green ones.

The preprogrammed PIC is only available from us, and is normally supplied with the PCB. However, spare PICs are available if you need one. Please enquire for the latest prices.

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.

This parts list does not necessarily agree with the values on the schematic. The parts list is the correct one to use.

Resistors

5% ¼ W or better unless stated

22R	R7
75R	R18, 29
100R	R15, 21, 36, 37
220R	R2, 4, 5
680R	R35, 32, 3, 1
1K	R8, 34, 33, 40
2K7	R23
4K7	R9, 10, 11, 12, 13
6K8 1%	R38
10K	R6, 14, 31, 16, 19, 27, 28
18K	R26

22K	R17, 25
33K 1%	R22, 30
36K 1%	R24

For TB3031 and TB3030 being controlled at 0.8V/octave

39K 1%	R20
4K7 1%	R39

For 1V/octave output with +/- 15V supply only

33K 1%	R20
6K8 1%	R39

TB3030 Resistors

100K 1%	R8
10R	R47, 48
82K 1%	R23

TB3031 Resistors

See TB3031 User Guide

Trimmers

Multiturn vertical mounted. Top adjustment

10K 22 turn cermet	DEPTH
10K 22 turn cermet	V.OCT

Capacitors

100nF polyester	C4, 9, 24, 16, 19, 3, 25, 23, 12, 11, 18
10nF polyester	C22, 27, 21, 28, 30
18pF ceramic	C2, 7, 26
33pF ceramic	C14, 20, 31
1uF, 63V electrolytic	C1
2u2, 63V electrolytic	C5, 8
4u7, 63V electrolytic	C15, 10, 17, 6
22uF, 25V electrolytic	C13, 29

Miscellaneous

4 MHz crystal	X1
Leaded Ferrite bead	L1, 2, 3, 4

Discrete Semiconductors

1N4001	Silicon diode	D3
1N4148	Silicon signal diode	D2, 4
BAT42	Schottky signal diode	D5
BC550/BC549	NPN transistor	Q1, 2
3mm LEDs	Green	LED1, 2

Integrated Circuits

LM336-5	5V reference	D1
4051	CMOS 8-1 analogue switch	U5
HEF4104BP	Low to high level shifter	U6
74HC04	Hex inverter	U4
78L05	100mA 5V regulator	U2
MAX551ACPA	12-bit DAC	U11
6N137	Opto-isolator	U3
LF412CN	Dual FET op-amp	U7, 12
TL072C	Dual FET op-amp	U10
AD712JN	Dual FET op-amp	U8
OP177G	Single bipolar op-amp	U9
PIC16F628	midiDAC PIC	U1

Connectors

4-way MTA 0.156" header	1 off optional PWR
3-way 0.1" Molex header	1 off optional M-THRU
2-way 0.1" Molex header	1 off optional M-IN
2 pin 0.1" header & jumper	RETRIG

Don't forget the sockets for connecting the tbDAC to the outside world. eg. Two 5-pin DIN sockets for the midi in and thru.

Building the tbDAC

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. To date this has happened only a few times across the whole range of Oakley PCBs. The most common error with four of these was parts inserted into the wrong holes. Please double check every part before you solder any part into place. Desoldering 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. 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!

The tbDAC PCB is flashed with solder around the pads. This helps the soldering process. Please note: this flashing is with solder that contains lead. You should therefore wash your hands after handling the board. It is also recommended that for best results this board is soldered with lead-tin solder.

I am currently using water washable flux in solder these days for my board manufacture. In Europe, Farnell sell Multicore's Hydro-X, a very good value water based product. You must wash the PCB at least once an hour while building. Wash the board in warm water on both sides, and use a soft nail brush or washing up brush to make sure all of the flux is removed. Make sure the board is dry before you continue to work on it or power it up. I usually put the board above a radiator for a few hours. It sounds like a bit of a hassle, but the end result is worth it. You will end up with bright sparkling PCBs with no mess, and no fear of moisture build up which afflicts rosin based flux. Most components can be washed in water, but **do not** wash a board with any trimmers, switches or pots on it. These can be soldered in after the final wash with conventional solder or the new type of 'no-clean' solder.

I have recently found that if you are using a very hot soldering iron it is possible to run your iron so hot as to boil the flux in the 'water washable flux' solder. This is not a good idea as it can create bubbles in the solder. If you prefer to have a fixed temperature iron, then it is best to get a 18W one for this purpose. I use an ordinary Antex 25W iron with a Variac power supply running at 205V. This seems to work well for 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 the diodes are in place, double check they are pointing the right way.

The crystal is marked as XTAL on the PCB. It is a good idea not allow the crystal's housing to lie up against the board's surface. By allowing 0.5mm or so between the PCB and the bottom of the crystal's case, you will allow water to wash away any flux, and prevent the case from touching the solder pads.

IC sockets are a good idea especially if this is your first electronics project. However, no matter what your experience is, IC sockets are strongly recommended for U1 and U11. Make sure, if you need to wash your board, that you get water in and around these sockets.

For the transistors, the regulator U2, and the reference diode D1, 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' jaws is parallel to the flat side of the transistor.

The polyester capacitors are like little blue or red 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 ceramic types are more like little square chunks of ... er, ceramic plate. These should go right into the boards. Cinching the leads can be tough on the fingers, because of the shortness of the leads. Make sure you are using 0.2" lead pitch types. If you have 0.1", you are very likely to crack the housing of the capacitor.

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.

I would make the board in the following order: resistors, IC sockets, small non-polar capacitors, transistors, electrolytic capacitors. Then the final water wash. You can now fit the trimmers and DIP switch to the board with no-clean or ordinary 'ersin' flux solder.

Connections

This very much depends on where you are going to use the tbDAC. I am going to assume you are building it into the same case as your TB3030 or 3031.

The tbDAC requires +/-12V and two grounds to work. These are obtained from the TB3030 or 3031's own power supply. Pin 1 of the PWR socket, should be connected to the +12V pad on the TB3030/1 PCB. Pin 4 should be connected to the -12V pad on the TB3030/1 PCB. Pin 2 and pin 3 must both be taken separately to the GND pad on the TB3030/1. Use one wire for each, and don't be tempted to join pin 2 and 3 together and take just one wire to the TB3030/1. Two separate paths are needed so as to reduce the digital switching spikes on the sensitive analogue ground.

The other connections **for a TB3030** are as follows:

tbDAC	TB3030	Detail
GATE	GATE	Gate signal
BND	CV1	Pitch bend
KBD	CV	Pitch CV at 0.8V/octave
VEL	VEL	Velocity

The MOD output is left unused on my prototype, but you could connect it so that it controls filter cut-off. The suggested panel layout for the TB3030 has the filter cut-off controlled by the velocity CV via a SPDT switch which can turn the effect on or off. For more control you could arrange the MOD CV to go to the other side of this switch. This way you could have the VCF under the control of velocity **or** the modulation wheel depending on the position of the switch. Its up to you, but remember that some keyboards don't have a decent modulation wheel but a bender instead, eg. Roland keyboards. This is fine for introducing modulation, but fairly hopeless at controlling things with any precision.

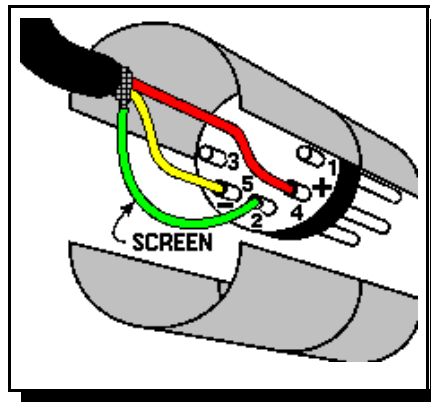
The other thing you can do is to have the filter cut-off only controlled by the mod wheel, and have velocity only controlling the accent-slide circuitry on the TB3030. If this is the case, you need to take the MOD pad on the tbDAC and connect it to the bottom pad of SW3 on the TB3030 PCB. Then take the VEL pad on the tbDAC to the top pad of SW3. You won't have any need for the two switches on the front panel in this case. This may be more suitable if you use a computer sequencer only.

Note that if you have an issue 1 TB3030 PCB, you also need to connect the +12V pad on the TB3030 to the OFFSET pad on the TB3030.

If you have a 3031, then please follow the connection instructions in the latest version of the 3031 User Guide.

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 tbDAC, chances are that you have wired up the midi socket incorrectly.



The diagram above was taken from the Philip Rees resourceful website and shows clearly the odd pin numbering on 5-pin DIN plugs. My thanks go to Philip Rees Ltd. for the use of this diagram. This UK based company produce a wide range of midi related equipment including merge and through boxes.

Trimmers

There are two trimmers on the tbDAC PCB.

1. **V.OCT.** Adjust this to give -5.01V at pin 7 of U11. This will make the KBD CV output respond to a law of 0.8V/octave. Alternatively, if you are using a +/-15V supply and are wanting to create a 1V/octave output, then pin 7 of U11 should be trimmed to -5.33V.

2. **DEPTH.** This adjusts the amount of pitch bend. Set this to your own needs. I normally set this to be exactly 2 semitones. This would normally be set once you have trimmed the TB3031's V/OCT settings correctly.

Final Comments

I hope you enjoy building and using the Oakley tbDAC.

Please feel free to ask any further questions about construction or setting up. If you cannot get your project to work, do get in touch with me or the Oakley Synths list on Yahoo groups. Sometimes, it can be the simplest things that can lay out a project. If we still can't get the completed and undamaged module going together, you can send it back to me to fix, but you will have to pay for postage both ways, any parts required and my time at £15 per hour. This service is taken up only very rarely, so it just goes to show how easy it is to get an Oakley project to work first time.

Please further any comments and questions back to me, your suggestions really do count. If you have any suggestions for new projects, feel free to contact me. You can e-mail, write or telephone me. If you telephone then it is best to do this on Monday to Friday, between 9 am and 6 pm, British time.

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 wrote the firmware that makes the midiDAC and the tbDAC so special. Thanks also to all those nice people on the synth-diy, AH and Oakley-Synths mailing lists.

Tony Allgood.

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