TENT Labs
11.2896
● low jitter

AD
797
0443
552295.1

WIMA
3,3µF
50−
U2

WIMA
3,3µF
50−
U2
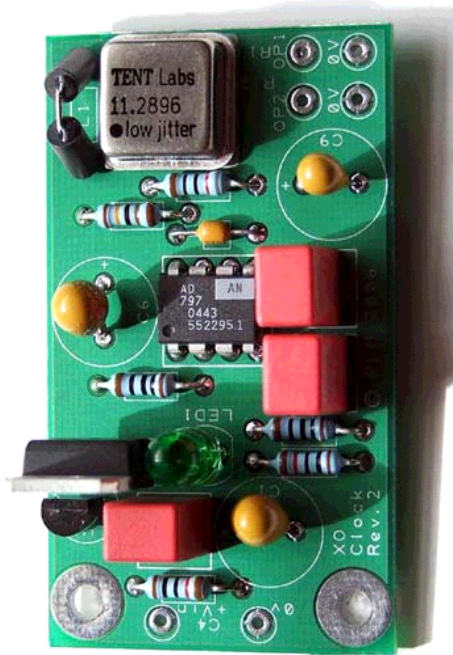
WIMA
3,3µF
50−
U2

XO
Clock
Rev. 2   © PFM 2006

the flea

a Pink Fish Media forum diy project

The PFM Flea is a very high-performance, low power voltage regulator optimised for (but not limited to!) powering an aftermarket clock, the TentLabs XO, for CD and DVD players. It's by bodgers, for bodgers, with many thanks to everyone who has shown interest and helped turn an innocuous PFM DIY room thread (http://www.pinkfishmedia.net/forum/showthread.php?t=18014) into a fully-fledged group project.

This short manual documents the Flea in four sections:
- A description of the circuit and its application for the experimenter as a summary of the originating thread.
- A short FAQ on implementing the boards and kits
- A step-by-step building guide for those who have purchased boards or the complete kit as part of a PFM group buy.
- An example installation in a CD player.

As a collaborative effort, **'the flea' is free for personal use**; share and enjoy.

However, please note that copyright for the design, including but not limited to the board artwork, has been assigned to the Pink Fish Media forum (http://www.pinkfishmedia.net/forum/index.php). Any enquiry regarding commercial application(s) should be referred to Tony Lonorgan as PFM forum owner.

Flea manual: second issue, rev A, 15.01.07:urls updated / martin clark, mc@acoustica.org.uk   Comments and criticism welcome!

2

Overview

This is a deceptively simple, high performance series voltage regulator based on the observation that for very light loads the usual error amplifier itself can source all the current you actually need. All it takes is a voltage reference, and a high performance op-amp.

It's like any circuit - no part of it is exceptional, all that matters is how (and why) the whole is put together:
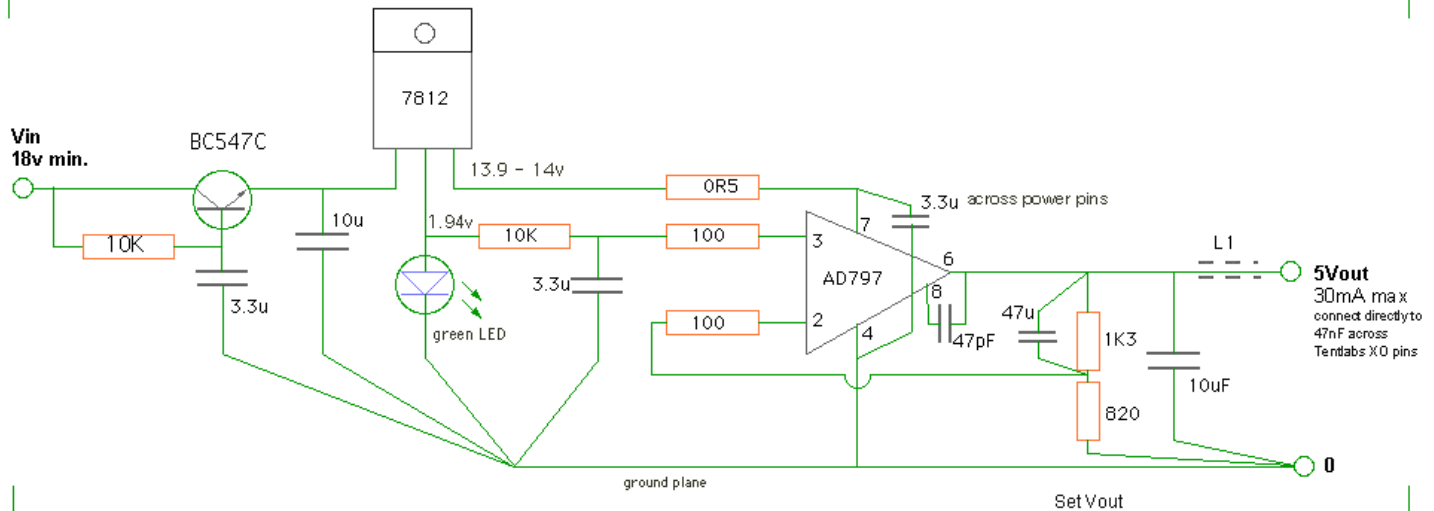
Starting on the left of the diagram, input can be supplied from a very simple PSU or any existing suitable voltage rail (18-32V). Incoming garbage is swept-up by the simple 'capacitance multiplier' (also known as a *gyrator*) at the input. The 10Kohm resistor and 3.3uF capacitor form a low-pass filter, which controls the pass transistor. Together these three components act as a low pass filter with a very low corner frequency (<5Hz).

Next comes a conventional three-pin regulator to provide a stable, low impedance supply to the circuit. The 7812 doesn't actually have to be very good at all - we don't even much care about its behaviour as a regulator here, since the AD797 has up to 130dB(!) of power supply noise rejection at low frequencies. The reference leg of the 7812 is basically the output of an internal current source, which we take advantage of to drive our voltage reference - a regular green LED - which gives about 1.95v. This reference output is followed by another 10k/3.3uF filter. All 3.3uF caps are film types to avoid adding leakage noise.

Key components

The weapon of choice for the amplifier is the extraordinary, low-noise AD797. This is both a very fast and very low noise device, with a slightly unusual architecture. As such it requires some care in implementation to get the best out of it in terms of regulator performance - and stability.

The first key issue is decoupling the op-amp. This should be applied right at pins 4 & 7. Note in the schematic at the top of the page the op-amp is supplied via a 0.5ohm resistor; this does double duty, stopping the 7812 oscillating with the film cap on its output, and providing a convenient place to monitor current draw (more on this below).

Low impedance signal inputs are key to getting the best noise performance from the AD797. In this circuit dominant impedances are the 3.3uF (filter) and 47uF (feedback) caps. Consequently there are 100ohm input 'stopper' resistors to provide damping at the AD797 inputs (pins 2, 3). These resistors have a negligible effect on noise but help stability in this non-inverting configuration with gain >1.

The two resistors at the op-amp output are the feedback divider and set the op-amp gain, and hence the output voltage. Here, the ratio is [(1300/820)+1] = 2.58 x. With the1.94v voltage reference a 5.0v output results. The 47uF capacitor bypasses the upper resistor (R6), providing additional AC feedback, which rolls off noise-gain and makes for even quieter output. In fact anything of 1uF or over is good here – although it should be of 'audio' quality. 1-3uF film caps, 10-220uF Silmics and tantalum and Os-Con capacitors up to 47uF have all been tried and work fine.

The novel internal layout of the AD797 gives **one major advantage**. Between pins 6 and 8 we can connect a small capacitor (ideally 50pF) that closes an internal feedback loop and has the effect of **reducing distortion and output impedance**. The effect at high frequency is quite dramatic - definitely of interest for a high performance regulator! (see the AD797 datasheet, figures 18 and 29 in particular.) The upshot is that impedance is held low a another *decade* over the uncompensated circuit; this little regulator performs better out well past 100Khz than an LM317T can manage at just 1Khz...

Such speed with low impedance requires a bit of care in application, and so following the feedback network is a 10uF output capacitor that is **essential** with the AD797; the op-amp will oscillate without - slightly unusual when op-amps usually hate capacitance on the output. The value can be quite small, if you wish to experiment I'd recommend 2.2uF minimum. Low ESR isn't needed, and a 10uF tantalum is ideal and virtually guarantees stability. Best measurements driving the clock module come from having an additional 47-100nF SMD ceramic right at the Tentlabs XO also. Finally, a ferrite bead helps with EMI control; as an alternative you can wind a simple inductor - 20 turns of wire in a single coil about 4-6mm diameter – but ensure you connect a 1ohm resistor in parallel (between the ends of the coil) to damp any tendency for the coil to 'ring' with load capacitances.

Care and feeding:

The Flea requires a **minimum 18v input**, which is spent as follows:

Voltage and current capabilities	• ~1.5V drop across the capacitance multiplier
	• 2v drop-out for the 7812
	• 12V for the 7812 output, plus 2v from the LED

Therefore 17.6v is about the absolute minimum guaranteed for function as-is. If you have slightly less available then swapping the 7812 for a 7809 is the most expedient solution, which drops the minimum input to 15V. However, this getting close to the lower limit of the AD797's qualified supply specification (+/-5v, or 10v single-rail) It is *just* possible to use an 7805, for an op-amp rail of 6.9v and minimum raw supply input of 11v; this has been built and tested, but you're on thin ice at such low overhead, and best performance or even basic function cannot be expected!

Maximum input voltage is limited by the rating of cap C1; call it 30v since it's not good to run caps close to the rated voltage. If you need more headroom to use and existing raw supply, up to 45v, then increase C1 to a 50v part. The BC547 is rated 45v minimum collector-emitter and the film caps are 50v so you'll have no problems with the cap-multiplier.

The **total current demand** is tiny, c.20mA. Actually, the AD797 draws about 8-10mA, the XO about 6-9mA (these both vary by sample) and the rest is sent through the LED and the feedback network (2.5mA @ 5v).

The **current output** this AD797-based regulator can provide is limited by dissipation in the op-amp. With the 7812 giving a 14v supply to the op-amp, 50mA is about the maximum the 8 pin DIP will tolerate, although the 797 can easily deliver 80-100mA! To keep thermal effects down, 30mA is recommended as a practical maximum - far more than enough for *three* Tentlabs XOs, or the analogue stages of a bitstream DAC and so on. We did say it was a *flea-power* regulator…

Stability and oscillation

The AD797 is infamous for being somewhat prone to oscillation, and despite all the measures taken to ensure stability it is wise to check…

Fortunately the give-away symptom is excess power consumption. Comparing calculated to measured current drawn is a robust check if you don't have an oscilloscope; if the circuit seems to be drawing significantly more than it should then it's *highly* likely the 797 is oscillating at HF. Given that, for example, the 797 draws 8-10mA and the Tentlabs XO also 8-10mA (for 15-20mA total), one would expect to see 8-10mV across the 0.5R. With the clock (or load) running, measure between the output pin of the 7812 and pin 7 of the op-amp - be very careful *not* to short any pins accidentally! If you start seeing 15mV or more here then further investigation may be warranted.

Circuit layout and ground plane design:
Comments by Andy Weekes

It's worth talking about this a bit more, especially as you have to think about the frequency components of the power too - as we all know by now, it's not just DC current flowing, but an element of AC too. The AC component comes from several sources, e.g. noise on the incoming supply, current variations in the circuits being powered etc. Herein lies the biggest clues as to how to solve the potential problems that arise.
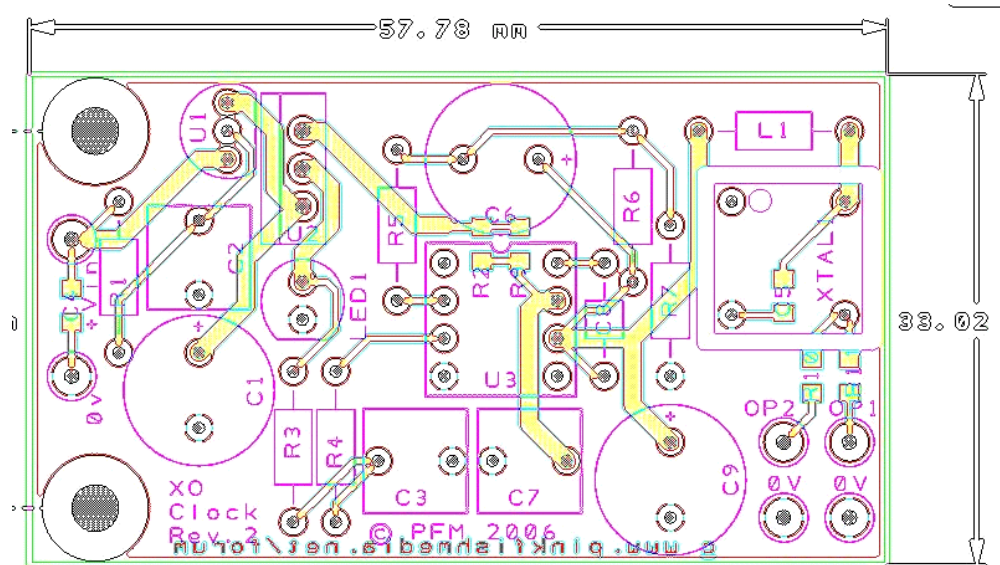
If we were to remove all the local bypass and decoupling caps, the current path in the ground plane would run under all of the traces associated with the current flow into the circuit, i.e. the flow in the ground plane would follow the path of least inductance, which is always going to be the point at which the traces have the smallest physical separation.

This results in a large 'loop' area which gives rise to both noise sensitivity and noise emissions problems. The key thing to realise is that all the current is flowing in that path, the DC and the higher-frequency components.

The HF components are the largest problem, the impedance of the ground paths at DC are easy to determine, they are simply the resistance of the copper traces or the plane area (very low, in a plane). As frequencies rise though, the reactive parts of the circuit become dominant - if the ground path looks inductive you now have problems with voltages at that point not being what you expect as the current flow in them gives rise to errors. The worst problems are the circuit elements can become resonant, as their inductance rises and stray capacitance dominates, giving rise to massive increases in voltage levels and radiated noise, or becoming high impedance and now being sensitive to EMI surrounding the circuit.

The key then is good decoupling. By adding local bypass capacitors we 'short circuit' the high frequency components on the rails to ground and provide a local reservoir of energy storage to deal with peaks in demand. If we do this properly, and ensure the loop areas formed by these decoupling components are as small as is practically possible, the radiation drops dramatically.

We're left with only the low frequency and DC components flowing in the secondary return path (which is the large loop area) and these are relatively trivial to deal with (but should not be overlooked in precision applications). The things to then look out for are 'high' currents flowing across the ground point for a critical circuit element, for example, giving rise to a DC or LF error as the ground potential at that point changes (through simple Ohms law). Remember all voltages have to be measured *relative* to something. If one part of a circuit measures it's voltage relative to a 'ground' that's at a different potential to another part of the circuit, you can give rise to an error that's equal to the potential difference between the points.

Now you know why the star point / single point earthing is so critical in precision measurement systems (which is what audio is!).

Another technique to further enhance this effect is to add some additional impedance in the PSU feed, this can be a resistor (Naim's 27R / 47u combo for example) or an inductor or some combination. You have to be careful though in different circumstances - ferrite-based inductors exhibit non-linearities that can sometimes be audible, air-cored inductors exhibit high Q and can form lovely resonant circuits with the high-Q decoupling caps. In this case we've added a 0.5R in series with the op-amp feed, this enhances the effect of the 3.3u cap and also means the 7812 doesn't see a high-Q circuit shorting it's output at HF, which might give rise to oscillation or quasi stability in the regulator.

At the input to the 7812 we have another cap, this acts in conjunction with the cap multiplier to further filter any incoming noise, so there's a current 'loop' here too (i.e. input pin, cap multiplier, 10u back to ground.

So this apparently simple circuit has had quite a lot done to it, to keep HF noise currents out of the circuit and well controlled.

Board Outputs

The Flea has several outputs:
5v (or whatever you set it to) is available from the position L1 if you just require a high-quality voltage regulator (No clock module fitted)
If you have added a TentLabs XO module for a complete clock solution, then up to two clock signal outputs are available at **OP1 and OP2**. Series termination resistors need to be fitted at R10 and R11 underneath the board to complete the circuit. Thee are SMD componenets and shuld be chosnto suit the input capcitance of the circuit served. Typically, these wil be 33-47ohms for a connection to a DAC clock input, and 47-100ohms to suit a decoder or digital filter clock input.

Is the AD797 the optimum device for this application? It's not that fast, plus I've heard many times that its stability is marginal. How about something like the AD817?

This is truly a board for experimentation, and I'd urge people to do just that, but collectively we've tried AD817, AD825, AD8065, AD8620, OPA627, some whizzo TI THSxxx something or other and nothing has come close to the AD797 here.

Due to the low impedances in the circuit at the op-amp inputs, bipolar op-amps are likely to prove quieter than FET types. This is probably of greater significance than increased speed – after all, op-amps have their gain fall-off with frequency, and much above 100Khz it is the bypass capacitors dominate voltage 'regulation'.

With the AD797 I would highlight the comment about the 'magic' of 47pf (50pf, ideally) cap. I think many here are going to be *very* surprised if they try listening to the clock without this cap, then add it once familiar. Its effect is little short of astonishing, sonically, in all the places I've tried it. (ALW)

In the interest of super-low cost I've retested the Flea using an NE5534. It's just fine, and *very* quiet, but because there are larger input currents, the DC precision suffers a little - ie more current flowing through the 10K filter resistor means there's a slight voltage offset. We're only talking a few mV though, not enough to need to alter any circuit values.

If another device is used, will the 100 ohm resistors at the op-amp's input be necessary?

No, but since the best-performing are likely to be bipolar (BT-based) op-amps, it would be good practice (and cheap insurance against one cause of instability) to retain them. Do omit the 47pF cap if not using the AD797.

The three polyester caps - is there a reason not to use say a small value Os-con instead? I wouldn't have thought absolute DC levels would be a problem here.

Os-cons, and indeed tantalum or Elna Silmic caps work fine in all positions. However – film caps don't exhibit leakage currents common to electrolytic types, which may impact noise performance in some positions – particularly the LED reference filter.

It would be wise to keep the film cap on the op-amp itself – this needs to work at HF to ensure stability.

If a 5v reference was used instead of the LED, could the potential divider at the output be done away with? Just looking at options to simplify the implementation.

If you wanted to use a 5v (or other) reference you could, but definitely keep the RC filter components - bandgap references will be more stable with temperature than the LED, but noisier! You can do away with the output divider with a 5v reference, *but* you MUST keep the 100ohm input resistors in that case with the AD797. Adding a 1Kohm resistor to ground would be a good idea too, to draw a slight DC bias current. So in the end you save...one resistor.

Incidentally, LEDs good low-voltage references. They are forward-biased PN junctions so noise is exceptionally low (<1uV over 20-20Khz) and the dynamic impedance is quite low too. Compared with an LM329 or similar LEDs are not

temperature compensated, and as a result the voltage will drift at -2mV/degC. Fortunately this really doesn't matter in this application where the reg will live powered-up inside the CD player where it's not exposed to rapid temperature fluctuations. As to which LED to choose - blue LEDs have a forward voltage of c.3-3.6v but seem to have higher dynamic impedance and noise. A standard, cheap green LED is optimal.

Is it best to take a feed from a separate analogue psu and run the 0v wire (only one) from flea to the star 0v used by the analogue psu/SRs or would it be better to run the flea's 0v wire to the ground plane near the DAC?

See the pictures below! **The best solution** is to **provide an independent** PSU just for the Flea. Although this may sound extravagant, a suitable transformer (0-15 or 0-18v, 3VA) will be both very compact and cheap. Follow it with a simple rectifier and reservoir cap (1000uF is plenty), and fed the raw DC into the Flea . The clock circuit is then galvanically isolated from the player, and the output 0v wire is *only* carrying the clock signal return. When the Flea is powered by an existing onboard supply via a single +ve lead, then *all* the noise currents from the raw supply bypassed by caps C1, C2, C4 are also returned to the raw supply circuit via the shared 0v wire. Providing an independent supply prevents this intermodulation happening, and the audible benefits are not subtle.

How do I connect the board if using an existing supply in the CD player?
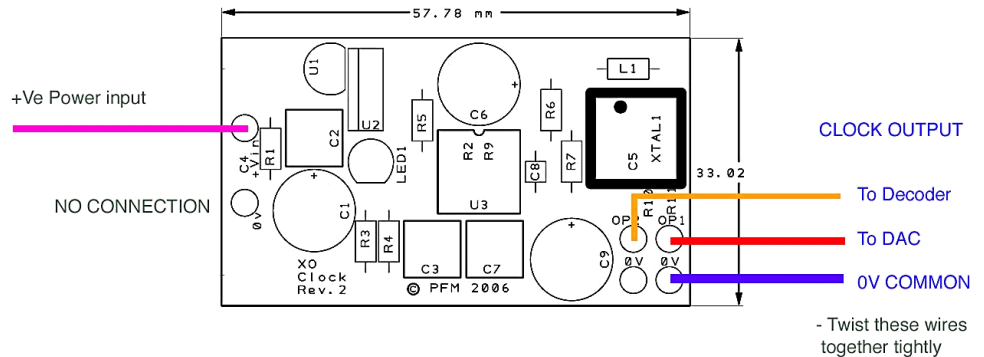
..So how do I connect the board to the CD player if using an independant supply then?
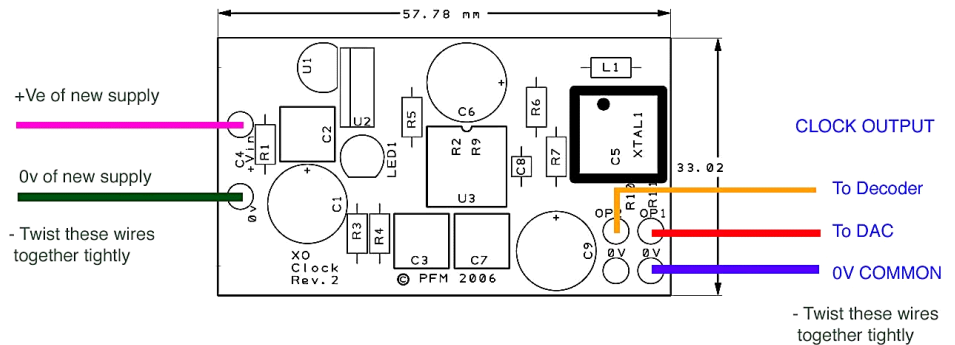
In both cases, run the 0v connection to the ground plane closest to the dac's 0v pin– eg.. the 0V connection of the local decoupling cap. Use a pair of wires lightly twisted together. If you power the Flea from an internal PSU supply only connect the output ground pin, close to the DAC chip, leave the i/p ground pin unconnected. The

analogue supply on a Naim CD3.5 /CD5 is ideal for this especially if you have an external PSU for the o/p stage [and it's available, from a *via* in the PCB, at just the right location).

Can I use the Flea for other purposes…?

Of course! the idea for this board is to provide a low-power but very high performance regulator for the experimenter.. so experiment!

For example, in the Naim CD3.5 (or many other CD players using Bitstream DACs) the dac chip has an onboard op-amp driving the output that requires a clean +5v supply. This can easily be supplied by a Flea – in the CD3.5, just remove the 3.3R resistor that links the DAC +Vin pin to its power source and replace it with the output of a flea (tapped from the +V and 0v holes for the XO module) There's no strict need for L1 in such an application - that's mostly to restrict noise from a clock - and in fact since this is an analogue audio path getting rid of the ferrite would be a good thing.

Just keep an eye on the current drawn by monitoring voltage across the 0.5R. In this example, the dac op-amp draws 6-9mA, about the same as the AD797 itself, so you should see a voltage across the 0.5R of the order of 12-18mA. If the current gets much above 30mA the flea probably oscillating – and adding a small series resistor at the Flea output, say 0.5R, will help keep things stable.

How about higher / other voltages?

At 30V input, about 0.7W is dissipated across the whole board when running a Tent XO, of which 280mW is in the op-amp. Not much, really; no heatsinking required.

30-40mA is a practical maximum output at 5V with the 7812 pre-regulator. The AD797 can deliver a lot more, but it's best to run things on the cool side for best performance and reliability. Still, 30mA is enough for *3* TentLab XOs, or the analogue stages of bitstream dacs, or quite a few such uses for a small experimenter's regulator come to that.

This total target dissipation maximum of approx 500mW should be kept in mind when trying other configurations. For example, using a 7824 and 30v raw input could allow output voltages in the range 2.5- 20V, but at a practical maximum of just 15-20mA since (20mA x 26v) will be dissipated in the op-amp in addition to its own power draw (8mA x 26v). Total, 696mW – uncomfortably close to the 0.8W absolute maximum permitted.

Dropping the input voltage, by using a 7809 in place of the 7812, might allow slightly higher current output at low voltages, but this voltage rail (11v) is getting close to the low-end of the 797s rated specs and

A 1Kohm, multi-turn potentiometer can be used as an alternative to the fixed R6, R7 divider if adjustability is required. Keep the bypass cap on R6 though, for best performance.

Off-load test
Andy Weekes:
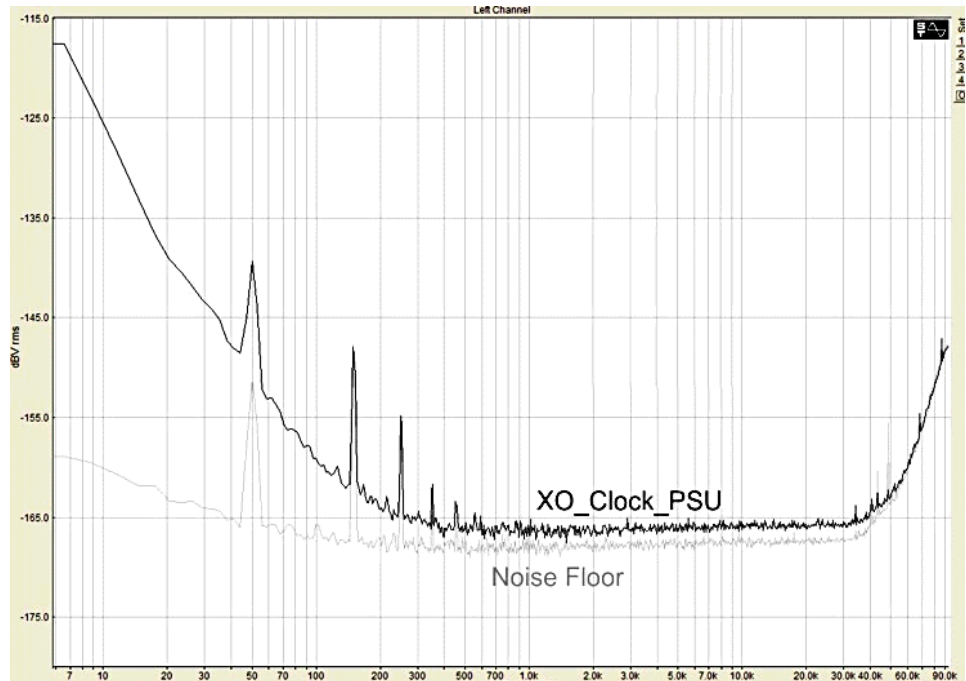
"Here's the off-load [Flea output] test, on-load measurements will have to wait until the Tent clocks arrive. The lower trace is the measurement noise floor, calibrated in dBV, the upper trace is the noise of the PSU.

Above about 300Hz there's barely a dB or so between the noise floor of my measurement system and the PSU for the clock module, below this the LF noise rises, almost solely due to the noise corner of the AD797. Above 30k the soundcard gets noisier and the PSU noise gets lost within it.

To put it into perspective, those traces are calibrated for 0dBv = 1V, and so -165 dBV is around 5 nV, or 0.000000005V within the narrow measurement bins of the FFT. At 10Hz, where the trace hits about -125dBV, that's the equivalent of 562 nV, or 0.000000562V.

At these levels it's pretty hard to keep the local EMI within the room, from TV's and mains stuff from contaminating things!* In short, it's quiet and it's stable…"

*NB this where the spikes of 50Hz and it's multiples derive from – note they also appear in the noisefloor*

Funnily enough there's nothing to see! The residual jitter is swamped by wander in the oscilloscope timebase, and the shape of the pulse is utterly determined by matching to the load (and to a lesser extent, by measurement technique). Nevertheless, it is a difference that can be heard quite easily.

There's some really excellent stuff on the measurement of jitter by the late Julian Dunn in the book he wrote for Audio Precision. The whole book available as a download here:
http://www.audioprecision.com/bin/AN-5.pdf

If you simply *must* have scope pr0n – here is a quick grab of the output of a Flea/ Tent XO combo driving a (punishing!) 50ohm load to 5v. Note the very clean response (little ringing), despite sloppy measurement technique and wide (250MHz) scope bandwidth:
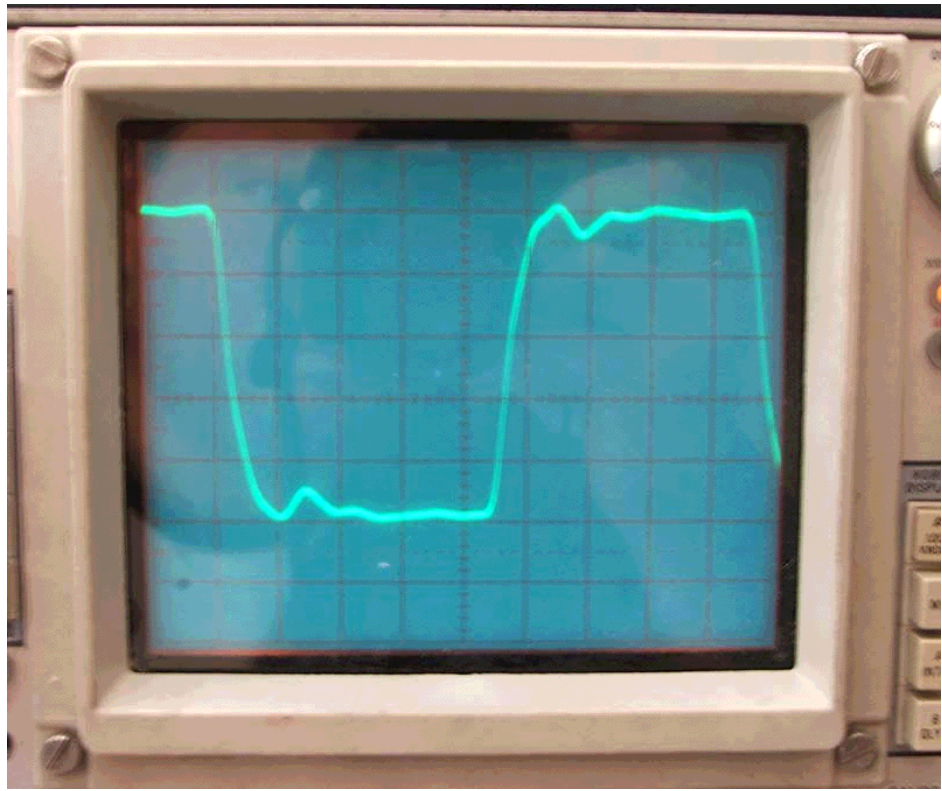
Equipment required

Soldering iron and solder; cutters, small pliers; multi-meter or DVM.

The PCB uses through-plated holes, which makes for reliable assembly. However – any mistake, such as soldering the wrong value resistor in place, is made more awkward to rectify without damaging the board. Using 'Solderwick' or an equivalent desoldering braid will help immensely and is strongly recommended.

Preparation

Before you start, **please take time to verify** you have all the parts to hand, and **check resistor values, capacitor voltage ratings and polarities.** A schedule of parts is given on the next page.

Resistor codes can be checked using a DVM, or by comparison here: http://samengstrom.com/elec/resistor/5band.html

For resistors like the MRS25s, with 5 colour bands, the first three bands are the digits, the 4th the multiplier the 5th the tolerance.

Errata

Two minor issues have been identified late in collating the full parts kits:

Resistors R10 and R11 were specified as normal MRS25 leaded resistors, when the PCB requires SMD components. Carl has endeavoured to provide suitable 100R and 33R SMD resistors as a late addition, so don't be surprised if you find a couple of 'spare' leaded components.

The 10uF capacitor (C1) before the 7812 voltage regulator was erroneously specified as a 10uF, 16v (tantalum) part. In fact this part MUST be rated at least 25v, and preferably 35v. Again, a substitute has been added to the kit but please ensure you install the correct voltage rating.

Component Schedule

Element	Component Value	Manufacturer	Manufacturer Part No.	Supplier	Supplier Part No.
C1	10u, 35V	MEC	MTAP106M035	Rapid	
C2	3.3u, 50V	Wima	MKS2	Farnell, CPC, Rapid	107423, CA01213, 10-2202
C3	3.3u, 50V	Wima	MKS2	Farnell, CPC, Rapid	107423, CA01213, 10-2202
C4	100nF, 50V	AVX	08055C104KAT2A	RS	464-6688
C5	100nF, 50V	AVX	08055C104KAT2A	RS	464-6688
C6	47u, 6.3V	MEC	MTAP476M016	Rapid	11-0650
C7	3.3u, 50V	Wima	MKS2	Farnell, CPC, Rapid	107423, CA01213, 10-2202
C8	47pf, 200V	AVX	SA102A470JAATB	RS	464-7091
C9	10uf, 16V	MEC	MTAP106M016	Rapid	11-0642
L1		(supplied with Tentlabs XO)			
LED1	Green LED	Vishay	TLHG5205	Farnell	104-5482
R1	10K	BC Components / Vishay	MRS25	Rapid	62-7538
R10	100R	PHYCOMP	232273461001	Farnell	923-7364
R11	33R	PHYCOMP	232273463309	Farnell	923-7305
R2	1R0	PHYCOMP	232273461008	Farnell	923-7127
R3	10K	BC Components / Vishay	MRS25	Rapid	62-7538
R4	100R	BC Components / Vishay	MRS25	Rapid	62-7446
R5	100R	BC Components / Vishay	MRS25	Rapid	62-7446
R6	1K2 / 1K3	BC Components / Vishay	MRS25	Rapid	923-7127
R7	820R	BC Components / Vishay	MRS25	Rapid	62-7486
R9	1R0	PHYCOMP	232273461008	Farnell	
U1	BC547C	OnSemi	BC547C	RS	348-9406
U2	7812	STM	L7812CV	Rapid Electronics	47-3314
U3	AD797AN	Analog Devices	AD797AN	Rapid Electronics	82-0470
XTAL1	Clock Frequency	Tentlabs		Chevin Audio (UK) / Tentlabs	

Assembly

R2, R9: 1R0
R10, R11: 33R- 100R

Start by installing the surface mount resistors on the underside of the board.
R2, R9 are in the centre of the picture and are connected in parallel – **note the orientation.**

R10 and **R11** are the series back-termination resistors for the clock outputs. Values in the range 47R to100R are usual, and Guido Tent recommends 47R for all applications. *(R10, 11 not mounted in photo)*

However, investigation showed the best waveform resulted from using 33R to drive the TDA1305 DAC clock input, and a higher values of 100R + for SAA73xx series decoder clock inputs. These are the values supplied in the full kit.

Next, add the two surface-mount ceramic capacitors:

C4, C5: 100nF, 50v

These parts provide HF bypass for the incoming supply and the XO module respectively

Turn the board over and start with the leaded resistors:

It's easiest to start with the smallest passive components, and finish with the most delicate (and expensive!) active parts:
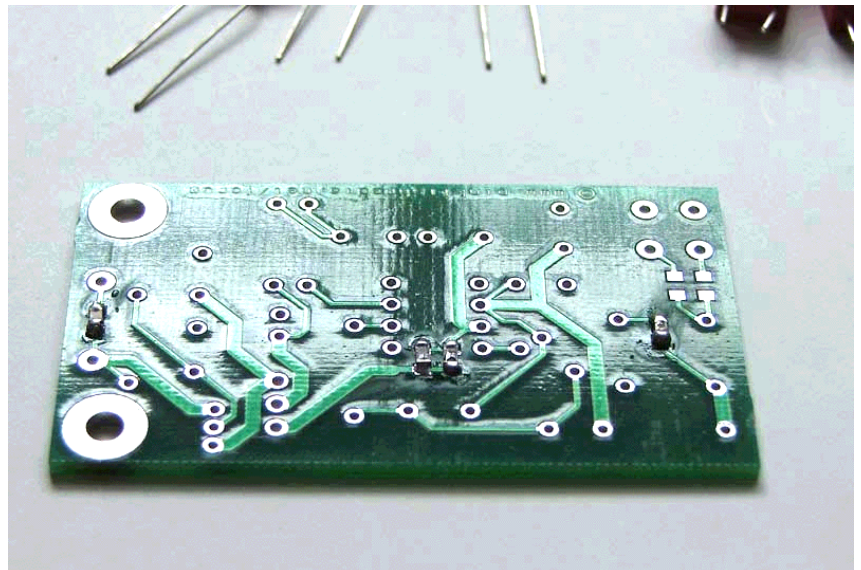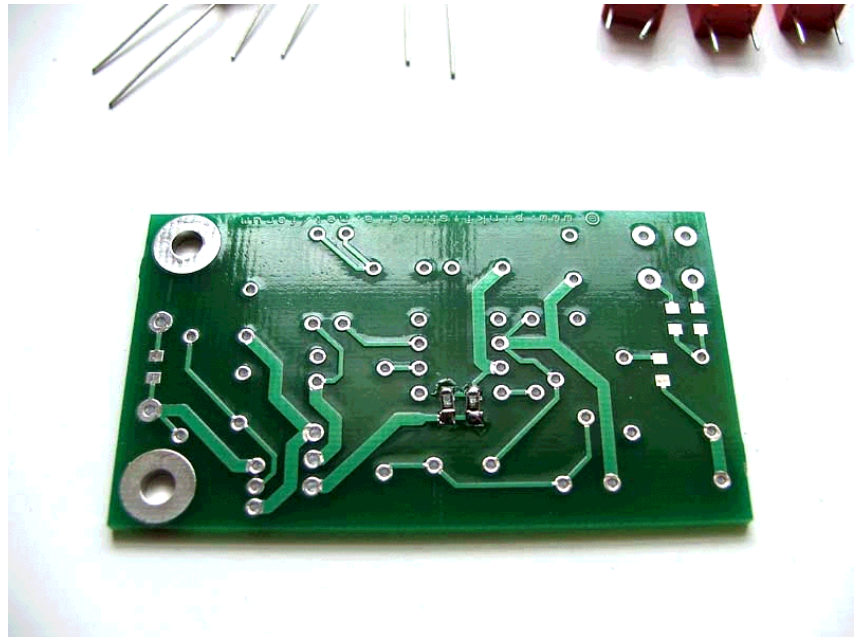
R1, R3: 10K

These are resistors used to form low pass filters, R1 on the capacitance multiplier, R3 filters the voltage reference LED.

Other values can be substituted, say 22-47K if desired, but these will delay start-up. This can cause problems in CD players – where the clock must start-up quickly for the decoder to maintain control of the motor servos. If the disc motor spins uncontrollably, you've gone too far – try 10K again for R1 and R3!
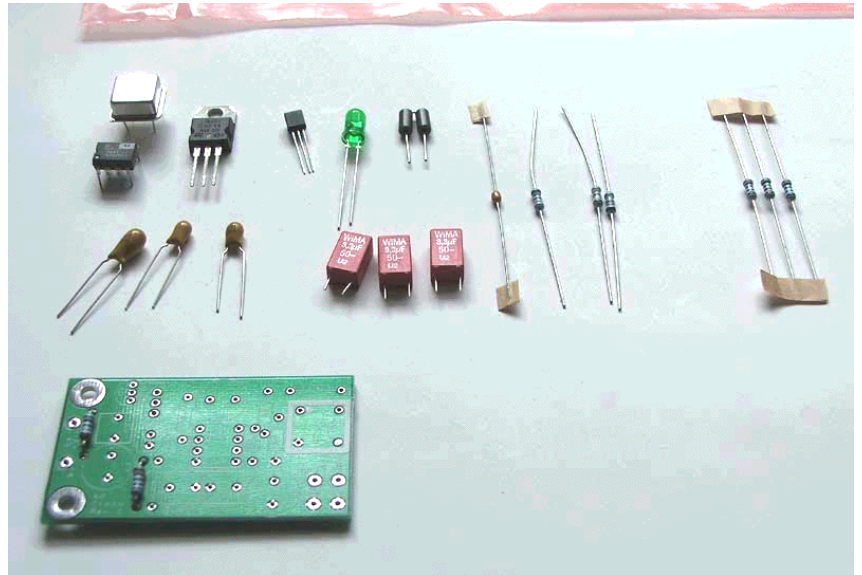

R4: 100R
R5: 100R

Since we now have some very low impedances seen by the inputs to the op-amp these are 100ohm input 'stopper' resistors for the AD797 These have a negligible effect on noise but provide damping which helps stability in this non-inverting configuration with gain >1. See page 10 of the AD797 datasheet for a detailed explanation.

If you wish to try lower-cost bipolar op-amps in place of the AD797 (e.g. NE5534) it would be good practice to still include R4 and R5.
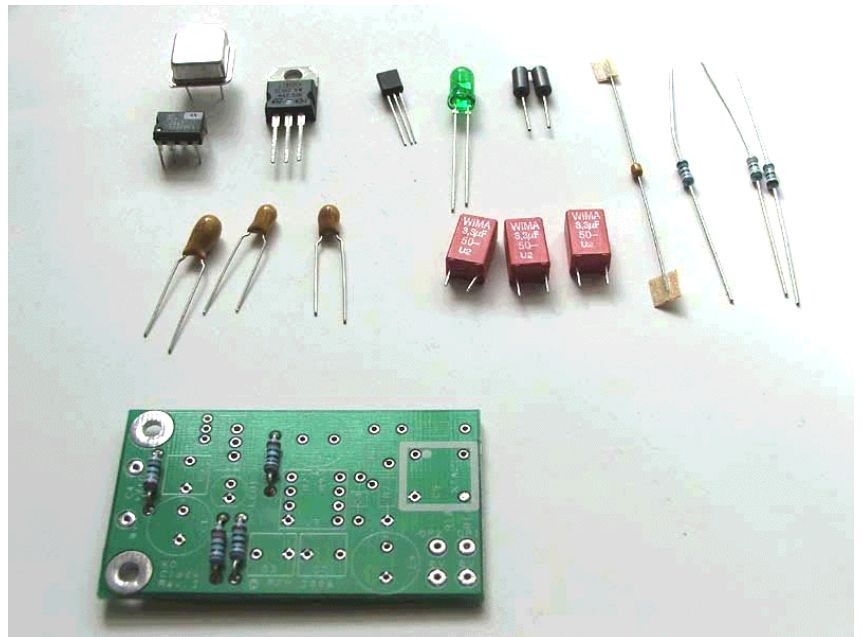
R6: 1K3
R7: 820R

These resistors are the feedback network, and set the output voltage.

Output voltage is $((R6/R7)+1) \times Vref$

R6 = 1300
R7= 820
Vref = 1.95V (approx.)

Output= $((1300/820)+1) \times 1.95$
$= 2.58 \times 1.95$
$= 5.04v$

In fact, because the LED drifts at about –2mV per degree C, the output voltage will be slightly less once installed in a CD player and warmed-up.
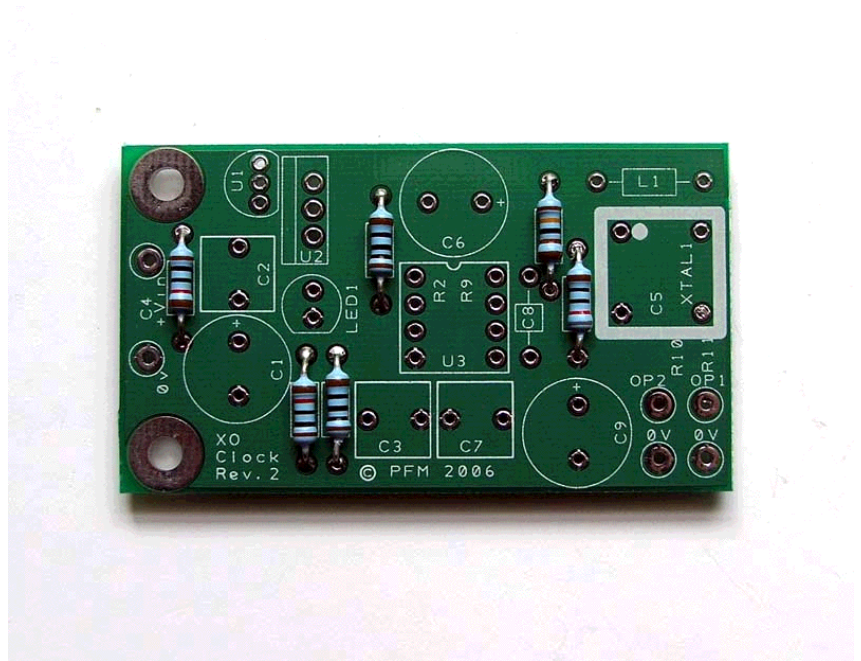

L1: ferrite bead
C6: 47uF, 6.3v
C9: 10uf, 16v

C6 provides AC feedback to the op-amp – it rolls-off noise gain by bypassing R6, which reduces output noise. It is in the signal path, so a good quality part should be used. If you wish to use the Flea at higher output voltages, ensure C6 is rated to match.

C9 is the output bypass cap; pick a voltage rating to match the application.

L1 is a ferrite bead provided with the TentLabs XO module. Alternatively, use 20 turns of thin insulated wire wound on a 6mm drill as an air-core inductor, with a 1R connecting the ends of the winding to provide some damping at HF.
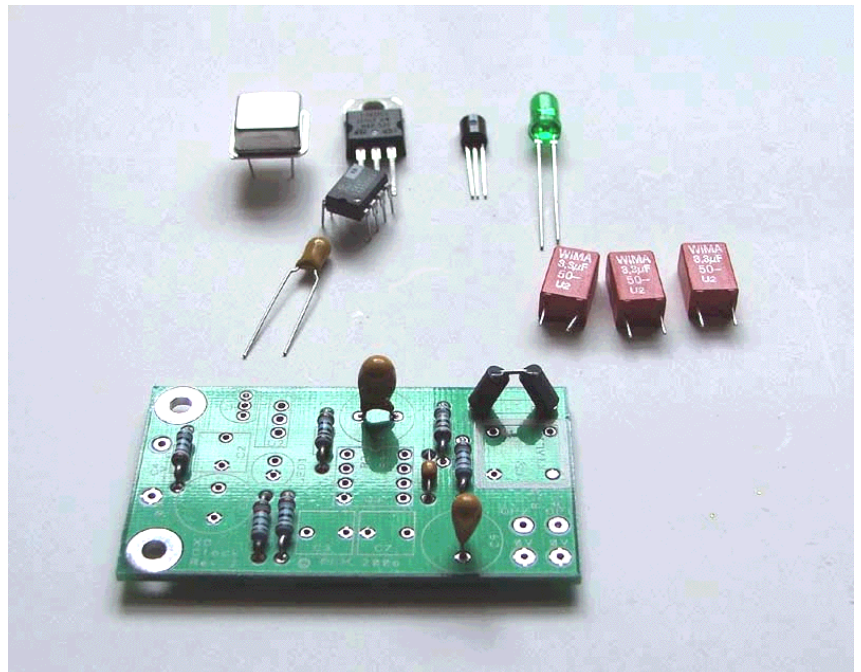
C8: 47pf, min 25v
C1: 10uf, 35v

Note **C1 must** be rated 35V minimum since it
provides input bypass before the 7812 pre-
regulator. It is polarised – check before soldering.

C8 is unpolarized. It is the 'magic' that makes the
AD797 work so well here. Connected between
pins 6 and 8 of the AD797 it closes an internal
feedback loop and has the effect of reducing
distortion by reducing output impedance. The
effect at high frequency is quite dramatic -
definitely of interest for a high performance
regulator! For more information see the AD797
datasheet, figures 18 and 29.

If you wish to try other bipolar op-amps then C8 is
omitted.
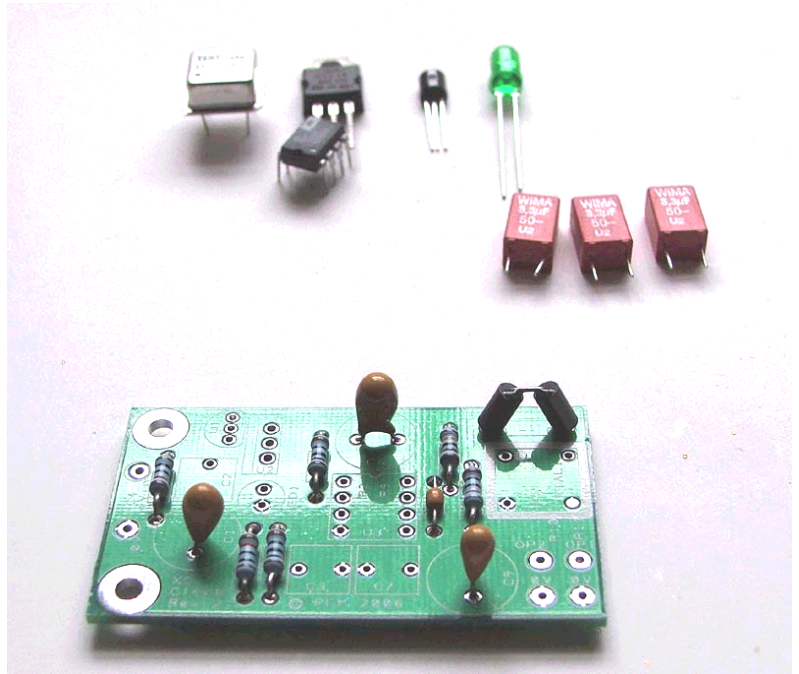
C2, C3, C7: 3.3uF film

These capacitors are used for filtering and HF
decoupling.

C2 is the filter cap for the input capacitance
multiplier.
C3 is the filter cap for the voltage reference.
C7 is the bypass cap for the AD797, for which
extended high frequency performance is required.

The use of sockets for the op-amp is to be
discouraged for stability reasons, especially with
the AD797. However - if you wish to fit a socket to
experiment with other op-amps then C7 should be
mounted directly across the op-amp supply pins
and not on the board as shown. Alternatively, a
second small film cap (eg 100nF) could be added
directly across the socketed op-amp's supply
pins.
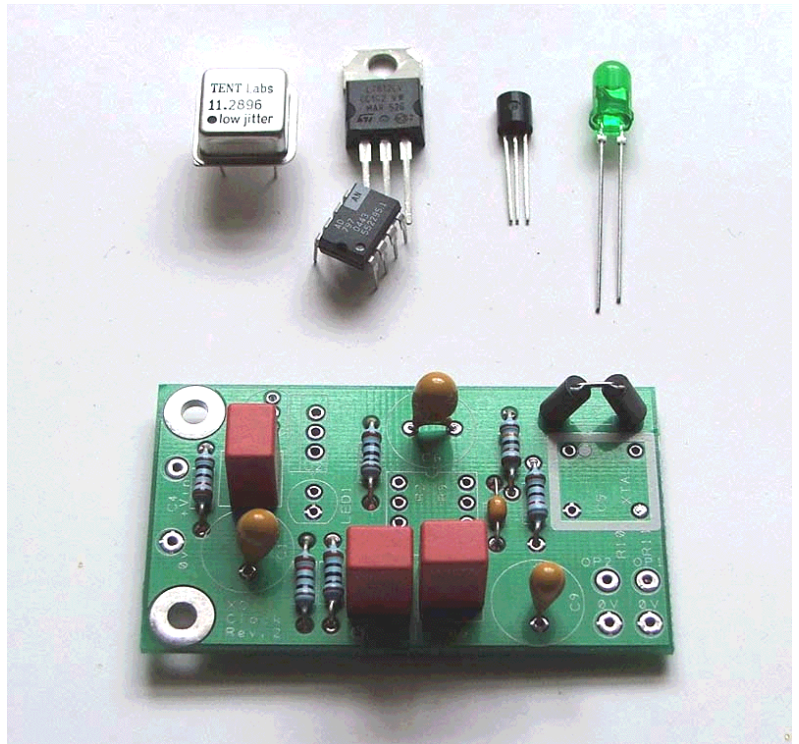
LED
AD797

The orientation for both parts is given on the board – match the cut-outs to the sikscreen pattern.

This LED is driven by a constant current source and forms a very quiet voltage reference – much quieter than bandgap references. The green LED supplied gives approx 1.95v; red Leds tend to fall around 1.6-1.7v, blue LEDs up to 3-3.6V – but there is some evidence that the blue types are also rather noisier.

Apply power, check the LED lights and verify voltages on the board: approx 14v at the output of the 7812 & at pin 7 of the op-amp; +5v at L1.

TentLab XO: at a frequency to match your application

The op-amp can be any bipolar type for lower cost but also rather lower performance than the AD797. FET-input op-amps are not recommended; with the low input impedances designed on this board they will give a noisier output.

Ready to go: output wiring mounted and ready to install. The clock signal is delivered via a short twisted-pair, with (in this case) 33R in series under the board. Add a second pair (and series resistor) if you also need a clock signal to supply the decoder separately.

Keep the signal connections as short as possible.
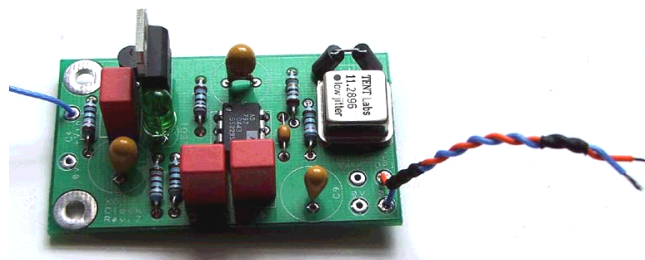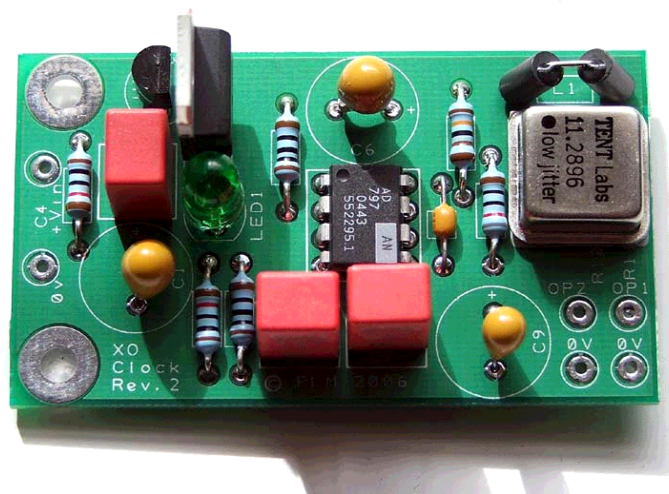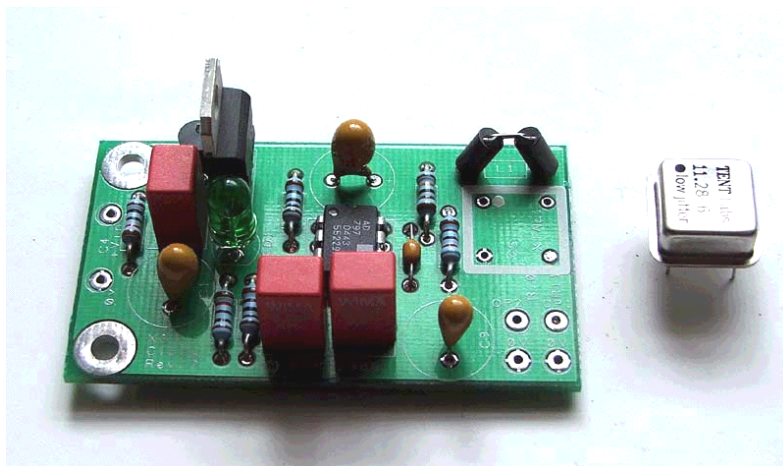
Here's a basic guide to installation. In the CD2, and other CD players based on the SAA7220 / TDA1541 chipset, the clock is usually located at the SAA7220 chip. For a guide to reclocking the Naim CD3.5 and 5 players (adaptable to other players which use a separate logic gate-based oscillator) please see the Naim CD3.5 mods page at www.acoustica.org.uk

Identify the main clock: this is formed with a logic gate (here, inside the SAA7220 digital filter), a clock crystal, two 'tank' capacitors (usually about 22pF) and a drive resistor that biases the gate into a 'linear' amplifier.

There may appear to be more than one such 'clock' in the player e.g. at the microprocessor – ensure you remove the right one! Processor clocks are usually low frequency, e.g. 4.00Mhz, and this will be marked on the crystal cases.

**Remove** the crystal and its two associated caps.

Verify which of the two pins on the relevant chip is 'clock input' (usually '**Xin**' on the part datasheet), and follow the trace to one of the holes vacated by the crystal. Feed in you new clock signal from the Flea's XO output here.

The other wire is the 0V signal return and connects the new clock ground plane to the original clock ground plane – use the pad in the plane vacated when you removed the two caps.
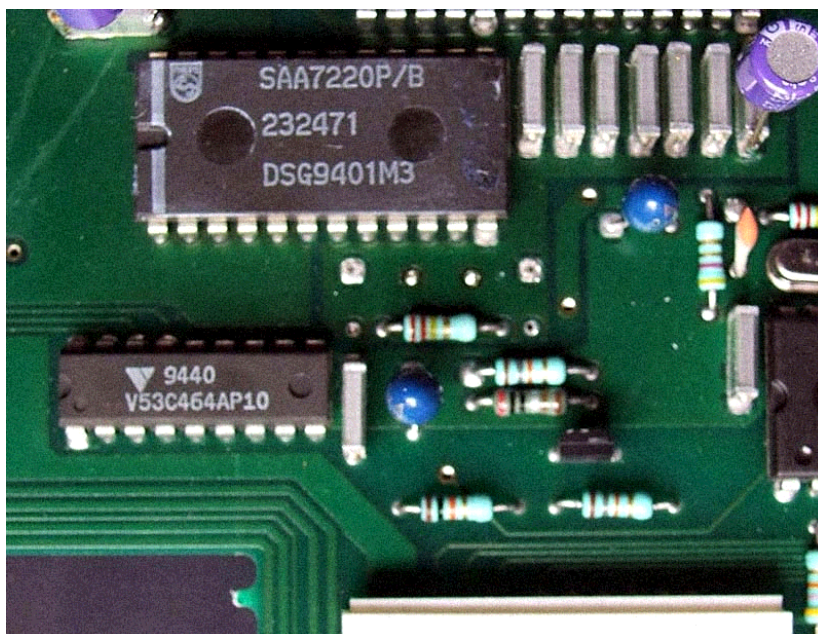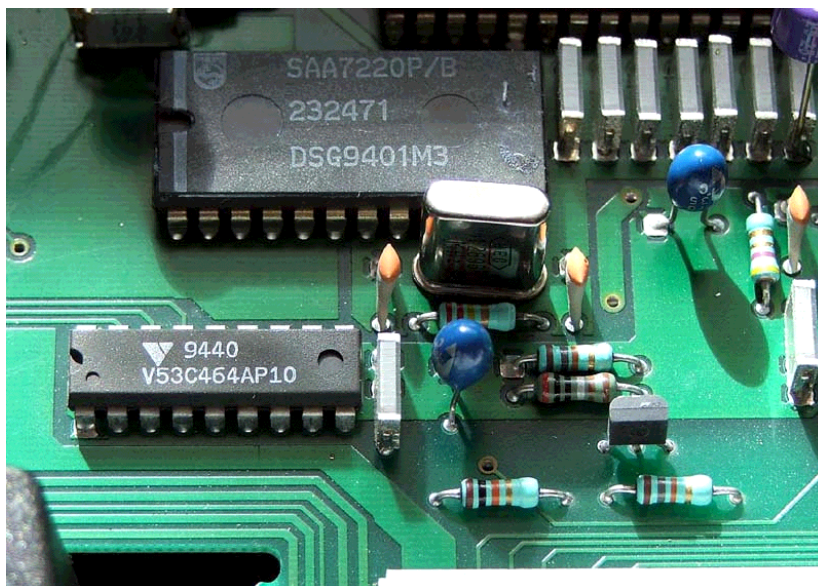
Try to keep all lengths and loop areas as small as possible. You'll need to locate somewhere to mount a standoff to hold the Flea, too. Here I've used a short length of copper wire soldered between a *via* in the ground plane and the (electrically isolated) mounting-hole pad.

Note power to this new clock is supplied from a completely separate PSU via the twisted pair of blue wires. This is **highly recommended**, since it avoids the clock signal return also carrying all the noisy PSU return current. The audible effect is not subtle!
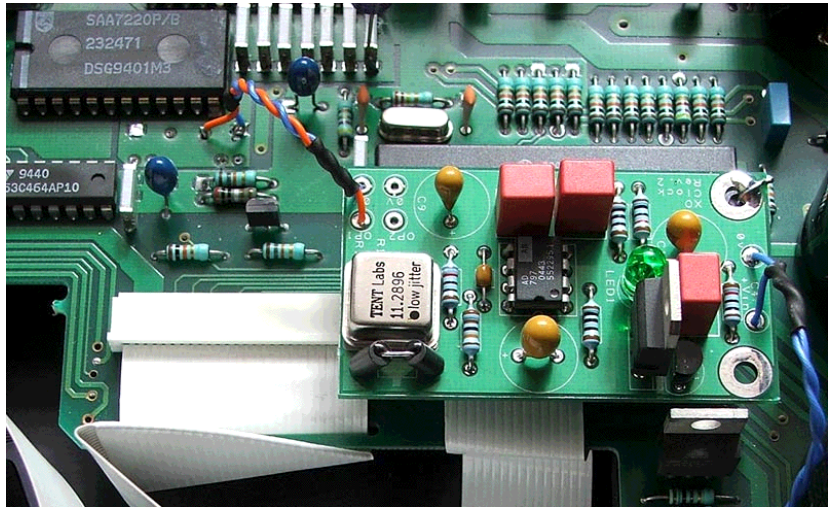
Success!
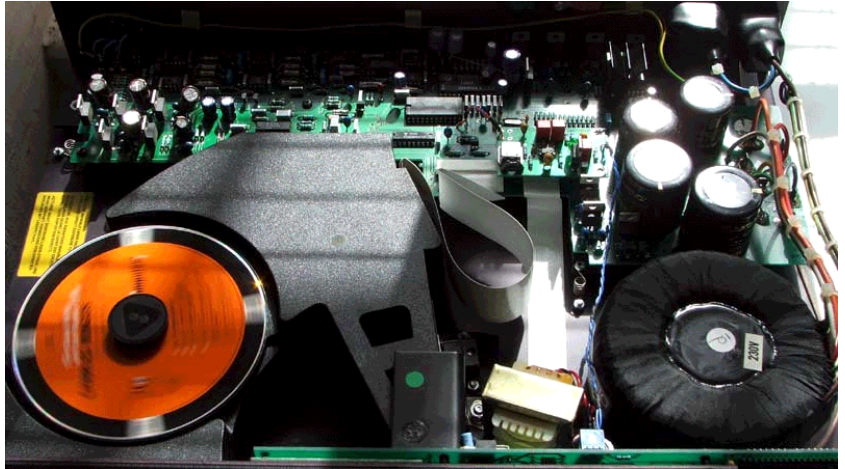
….Now put the toys away and get some music on

Further reading: here is excellent guidance to installing a new clock in your CD/DVD player. These are provided by TentLabs / Guido Tent, but please don't pester him if you run into difficulties with the PFM Flea – ask on the PFM Forum.

http://www.tentlabs.com/InfoSupport/Datasheets/page21/page21.html
http://www.tentlabs.com/Support/Mounting/XO2mounting.pdf
http://www.tentlabs.com/ProductEntities/XO/XO.html