Pedja Rogic

AYA DAC

TDA1541A non-oversampling DIY DAC,
Revision 2.0c

Manual rev.A
31 August 2007

www.pedjarogic.com

1. Circuit Description

Standard input coupling option in this revision is transformer, with primary ground left floating, and by one capacitor decoupled and differentially terminated secondary. Used transformer is the Scientific Conversion SC944-05 but footprint is also compatible with Pulse Engineering PE-65967 and PE-65612. (With 1:1 transformers like these the R103/R104 have to be 37R5.) Existing layout also enables possibility of capacitor coupling input without much fuss. Additionally, advanced builder will find the footprint of the resistor needed for capacitive coupling usable also with transformer for double termination.

CS8414 and TDA1541A communicate via I^2S protocol and are configured accordingly.

BCK and WS signals are reclocked before enter the TDA chip. Reclocking scheme remains as shown within the previous DAC projects but now only one flip-flop is used per line and only BCK and WS lines are reclocked (both changes are done like a compromises with layout). The principle and manifestations related to such reclocking are already thoroughly explained, so for more info please refer to the two existing documents:
www.pedjarogic.com/1541a/pdf/ASR_Measurements.pdf
www.pedjarogic.com/1541a/pdf/AR_Measurements2.pdf

VHC logic is now “officially” suggested both for its good sound and for its tolerance with regard to the mismatching between the data/clock and supply voltages, handy in case the 3.3V XO is used.

Suggested clock is still Crystek C3291. If one settles on frequencies above 50MHz, the solution may be the 3.3V Crystek’s C339x series (Mouser, www.mouser.com , currently doesn’t sell C3291 units above 50MHz in quantities below 25 pieces). In this case the XO’s supply has to be set to 3.3V and this is accomplished by the use of 4V7 Zener for D33 and then finely tuned by the current source supplying this diode (see the part that discusses supply voltage issues for more info on this).

As for the 74VHC74, the pieces made by Fairchild were in my experience pretty normally triggered by 3.3V clocks. The 74VHC74 can be also supplied with lower voltages and still accept 5V signals at its data input, however, as I’ve expected, I found it sounding better if supplied by 5V. Those more suspicious may settle on VHCT series which is 5V part specified for triggering around 1.4V (TTL input) and thus probably better suited for use with 3.3V clock. (However, since up to date I haven’t tried VHCT I don’t know if they differ sonically from VHC. Other candidate which I also haven’t tried would be 74LVC74A.)

RO2, RO3 and RO4 footprints, which are regularly unused, may serve for further ideas related to the I^2S level shifting or signal conditioning. The components placed here will be between the outputs of R106/R107/R108 and ground.

I’ll summarize a few things told earlier about non feedback output stage based on the Analog Devices’ AD844. The output current of the TDA1541A is led to the AD844’s inverting input. AD844’s non-inverting input is here the voltage reference and is tied to the ground. The TDA1541A’s output current flows into the AD844’s array marked with blue and is mirrored to another array (marked in green). In the classic opamp connection the output voltage would be set by the feedback but since AD844’s transconductance node (TZ) is externally available we can use it to set the output voltage using (relatively) low impedance load at this point and thus get rid of the feedback and problems it brings in the DAC I/V applications (though, of course, a feedback will improve the static distortion performance; please have a look at the DAC Measurements pdf file following previous DAC revision, you can find the link below). This voltage is then buffered by the AD844 output stage (the diamond buffer, marked in yellow). External connections/components are marked in red.

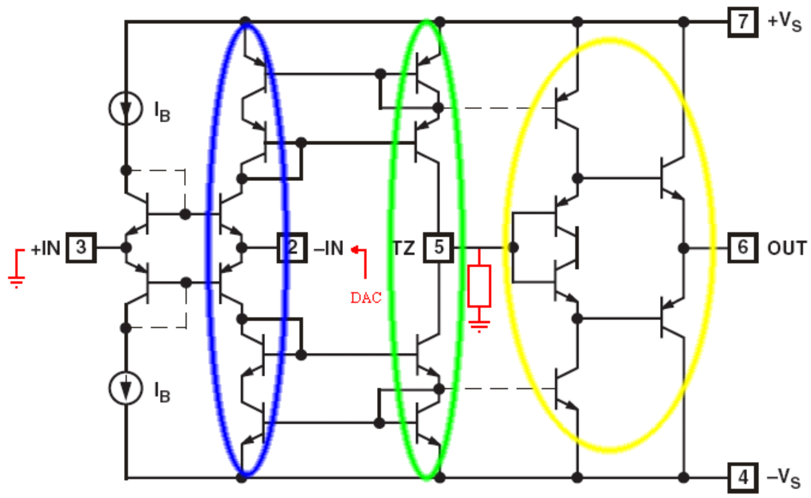


Figure 1

The simpler option at this point still includes an I/V resistor, additionally bypassed by the cap, but in this last version there is also provision for simple sin(x)/x compensation. Only one additional part is required for this and it is an inductor in series with I/V resistor, and in this case the bypass cap’s value is changed and it bypasses this whole series connection.

With 1k5 I/V resistors, the output voltage is about 2.1V RMS (output voltage is equal to TDA's Iout (4mA) multiplied by I/V resistor’ value, so 6V; this is the peak-to-peak value so RMS is 6V/ (2*sqrt2) = 2.1V).

Also like before, since the TDA1541A’s output current is the (unipolar) current sink swinging from 0 to -4mA, additional (adjustable) 2mA current source is used to null this offset and let AD844 work under better conditions i.e. without offset. In such a configuration i.e. without a feedback, it will start to show worse distortion performance with offsets above several hundreds of mV. A JFET current source is used. The trimmer has to be set to provide as low as possible offset (in mV) in the AD844's pin 5. Initial trimming has to be done right after the power up but because of the thermal drift after the power up, it has to be trimmed again after a couple of minutes. After then no additional trimming is needed and drift of a few tens of mV in regular use is normal.

Since the TDA1541A's output absolute phase is inverted and since this stage inverts the phase too, the DAC as a whole has correct polarity.

Distortion measurements of the AD844 c/b stage I have posted within the previous DAC project:
www.pedjarogic.com/1541a/pdf/Dist_Measurements.pdf

In this version a simple sin(x)/x compensation circuit is offered. Please note that the I/V resistors have two pads at their ground sides; one has to be used without compensation (resistors go directly to the ground) and the other has to be used with compensation (resistors go to the ground via inductors). More info on such compensation can be found here:
www.pedjarogic.com/1541a/L-sinc.htm

Please also note that I don't recommend such compensation entirely and unconditionally. You have to try it if you like it or not. Among the other things, it somewhat deteriorates linearity of AD844.

Other than the suggested AD844 common base I/V stage, a regular opamp I/V again can be used too. In that case, you have to remove C120/C121/C123/C124 and LO1/LO2, and to move R112/R116 between opamp pins 2 and 6. Generally, any unity gain stable single opamp can be used but up to a few weeks ago I haven't found any opamp able to compete AD844 c/b. Trying OPA627 lately changed a bit my mind. But, most shortly speaking, if you go with opamp I/V, please use OPA627.

2. Supplies

2.1: TO-92 fixed regulators for CS8414

Receiver's supplies, though still fully separated for Vd+ and Va+, are for the practical reasons somewhat compromised and are done with small TO-92 fixed 3 pin integrated regulators. It is **not** recommended just to use the first samples you have at hand or you can find in the shop around the corner, but to look for better performing parts. With noise and PSRR rather associated to the TO-220 parts but somewhat better transient response, Zetex ZR78L05 and ZSR500 will do fine. Some low drop units can be fine as well, like Panasonic AN8005 with a bit higher noise but a bit better PSRR.

Regardless of the care taken about selection of the regulator IC, it is true that at least receiver's PLL supply could deserve more attention, however a bit of trust is put into the downstream reclocking and hence reclocker supply is done more ambitiously.

2.2: Non-feedback regulators for the oscillator and TDA1541A

Most of you may be familiar with this regulator topology, which is the same as the one I've intended to the gainclone and described in the following page (please scroll down the linked page and find the last shown regulator):
www.pedjarogic.com/gc/supplies.htm
Regulators used in this project for the oscillator and TDA1541A can be understood like its scaled down version (in the term of their current potentials) and are also a bit easier with regard to the stability (a classic instead of the triple Darlington).

a) The circuit

The regulator used is principally very simple and boils down to the buffered voltage reference. This basic conception is improved by use of the current source for the voltage reference, then by use of the low pass to filter the Zener's noise, and finally the pass element is Darlington.

The figure 2 shows the working voltages of +5V and -5V regulators. Positive and negative regulators differ somewhat in a way the voltage references are configured (N-JFETs are used to source the current in both) and, of course, in the pass transistors types used, but the principle is otherwise the same. There is about 1.2V across the JFETs' source resistors whose value is 200R which means the current they source/sink is 6mA. (There will be more info on how to set the current with a JFET current source in the part b of this chapter; in the same part b there is the whole Id vs. Rs curve for the JFET SPICE model used in this graph; Idss of this piece is 24mA.) Shown Zener's voltage with this current is 6.23V. This voltage is then filtered by RC network (2k2, 10uF). A slight drop of this voltage before it reaches the base of the first transistor is the product of the 2k2 resistors and the first transistors' base current. If high hFE BC547/557 (so -C range) transistors are used, this current and thus this voltage drop will be negligible within the total figure. Then we have more important drop on the Darlington of about 1.3V which is the sum of the Vbe voltage of two used transistors, thus the resulting output voltage is 4.9V, quite fine for our purposes. The -15V regulator differs only in the value of the used Zener.

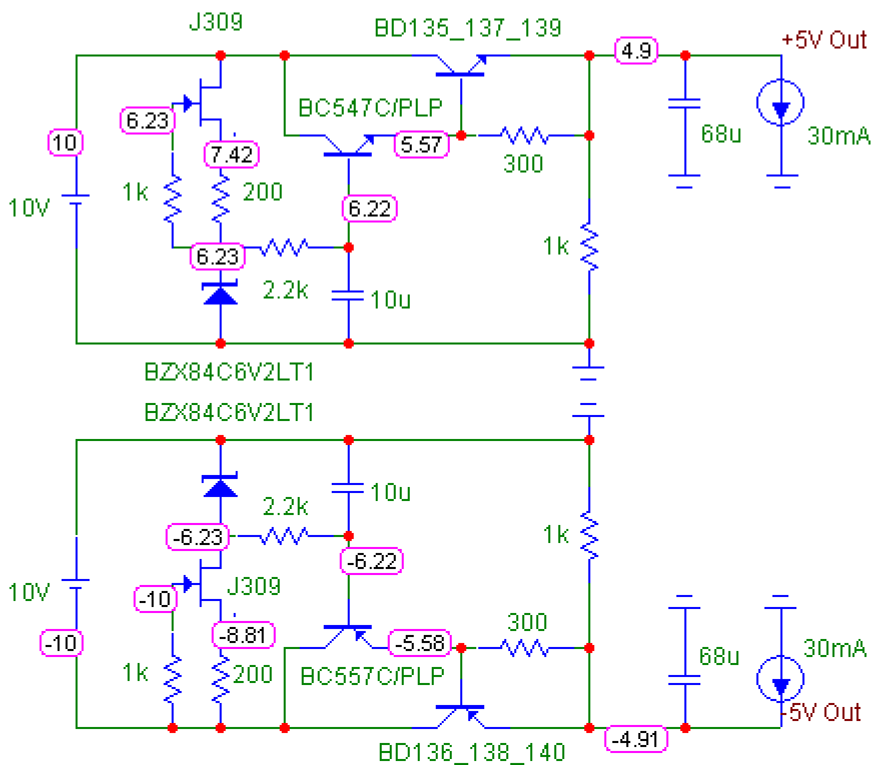


Figure 2

In practice there shouldn't be any problems with this circuit but since the actual Zeners' voltages vary in production and since the same goes for the transistors' Vbe, please remember: <u>the output voltage of these regulators is always equal to the Zener's voltage minus two transistors' Vbe voltage drop</u>. Please also note that the recommended operating voltages for TDA1541A 5V supplies are 4.5-5.5V where 7V is the absolute maximum, and recommended voltage for 15V supply is 14-16V and limiting value here is 17V.

Comparing to the feedback constructions, the output impedance of these regulators is relatively high. With such regulators the output Z is calculated by Shockley's relation, which means it is inversely proportional to the current and is ideally 1R at 26mA (in practice it is closer to or a bit above 30mA). The TDA1541A, as is claimed in the datasheet, draws 25-37mA (typical) per pin so most roughly you may consider output Z about 1 Ohm. However, at higher frequencies the output Z is anyhow managed by the capacitor rather than by the active circuit and what is good about such regulators is that they have excellent transient behavior and their inductive raise is no problem to match with the output capacitor (i.e. no peaking).

R7, R23, R28 and R33 are the loads for these regs and are needed for the testing purposes (these regs normally won't work unloaded) and are set to draw about 5mA. Note that somewhat more than 2mA of this current always pulled by 300R resistors through the first Darlingtons' transistors. This means that these resistors are not needed in normal operation but they must be used to check the regs before putting the TDA and XO in, and this is strongly recommend. They also can be used in the normal operation to pull more current from the regs (I=V/R) thus lowering their output impedance (as per Shockley's relation above). If you settle to lower the output Z lowering the values of the loading resistors please note also that this will raise the power dissipation on the second Darlington transistor. And watch the power rating of the loading resistors themselves (power they dissipate is V^2/R; it is the good practice to use resistors rated at least twice higher than needed).

b) JFET current sources

The current sources for voltage references in the XO's and all the TDA1541A's regulators are done by use of the JFETs. Other than these, there are two JFET based current sources nulling the TDA's output signal offset current. The first four are accomplished by J309 (or J310) and the second two by BF245A but the principle of operation is the same. Below you'll find the explanation on how JFET constant current source works and how to set its current.

When JFET's gate and source voltages are equal, which includes the case when they are tied together, the current flowing through the JFET's drain (Id) is constant and defined. This current is called drain saturation current (Idss). Since the gate (leakage or excess) current is negligible in comparison, the current flowing through the JFET's drain is practically also the current flowing through its source.

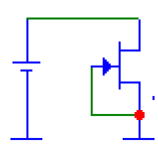


Figure 3

Raising the voltage between the gate and the source (Vgs) we can control the drain current and set any value less than Idss. Relation between the Vgs and Ids is unique for each JFET type and is normally given in the datasheets. This relation is called a transconductance. Inserting resistor in the source of the JFET we can achieve certain point from the transconductance curve and relation between Vgs, Ids and this resistor's value is covered by the simple Ohm Law.

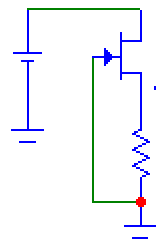


Figure 4

Since a transconductance curve is Idss dependent and since the Idss of JFETs varies in production and tolerances are not small, to choose the right value for this resistor we would have to know the Idss of the used sample. Manufacturers are sometimes helpful making ranges of the certain pieces with regard to the Idss (so we have BF245A, -B and –C, and we have 2SK170GR, -BL and –Y). In fact, J309 and J310 is almost the same part, just divided in two Idss range (12-30mA and 24-60mA), however we don't know the actual Idss of the specific sample before we measure it. Is there however, some simple answer about how to determine needed resistor value that may get you free of this?

<u>So, the answer is</u>: as long as you are not making 3.3V supply for the XO, i.e. as long as you use only 6V2 and 16V and not 4V7 Zener (you'll see a bit later why), the value of the current of the J309/310 current source is not highly critical but it still has to be kept between <u>3-8mA</u>; because of this relatively wide tolerance, not measuring Idss, <u>the use of 160R with J309 and use of 330R with J310 should guarantee the current in fact set within these boundaries</u>. Of course, once you put the actual resistors in, you should check the actual currents measuring voltages across them and dividing them by the resistors values.

Let's however get into more detailed answer. We can measure JFET's Idss using the basic connection from the picture below i.e. tying the gate to the source and putting the mil Ampere meter into the loop and watching the current flowing through. You have to try to control a JFET's temperature and to be fast – after the power is up the JFET will quickly start to heat and Idss to decrease. Please note that J309/J310 are relatively high Idss devices so running them at Idss is actually safe only at pretty low voltages.

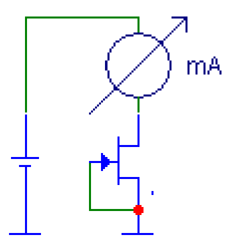


Figure 5

Now, knowing the Idss and targeting specific current, say 6mA, we determine needed resistance next way. Let’s have a look at the Vishay’s J309/310 datasheet.

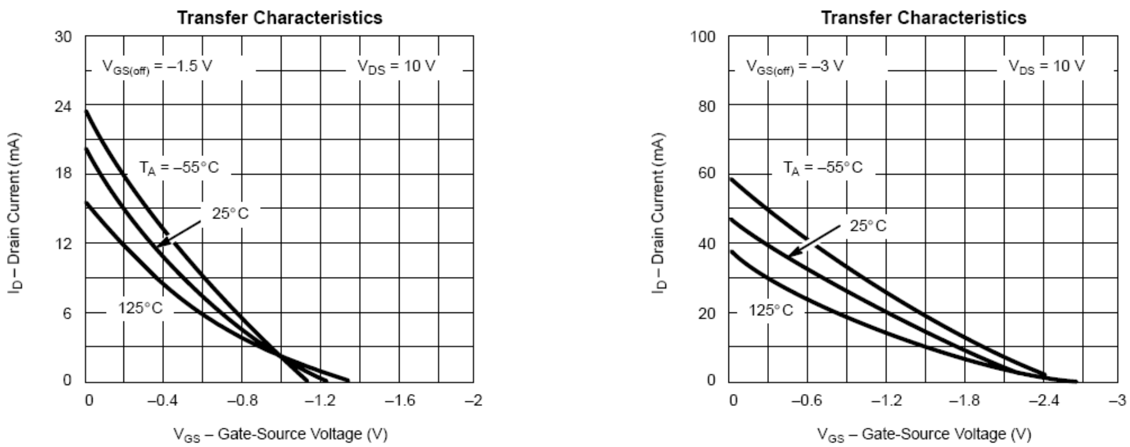


Figure 6

Let’s suppose that we measured that our piece had Idss of 20mA (at 25°C). The graph above says that at 6mA its Vgs voltage is about 0.7V. Simply applying Ohm’s law we come across needed 117R (so we’ll probably use 120R) in its source. The second graph says that a piece with Idss of 48mA at 6mA has Vgs about 2V, so we’d need about 330R for this 6mA. And what if your sample has Idss for which is not given a transconductance curve, say it is 30mA? This is actually easy since the Ids with the given resistor is directly proportional to the Idss, so its Ids will be 50% higher than the Ids of the piece which Idss is 20mA.

You may also note that these values are valid at the given Vds (drain-source voltage, here 10V) and at higher voltages the current also will be somewhat higher (please note also that this raise won’t be quite linear).

Also, trying to simplify needed work I’ve made the graph showing relation between Idss and source resistance and resulting Ids for J309/310. The graph is made using Philips’ supplied SPICE models with Idss of 34mA (blue curve) and 55mA (pink curve), respectively. Simulation matches relatively well to reality, however further 10-20% variations can be expected because of the drain current’s temperature dependency. This mainly means that if no special measures were taken during the Idss measurement and the result is taken right after the JFET was held by hands, the actual Id will be a bit higher.

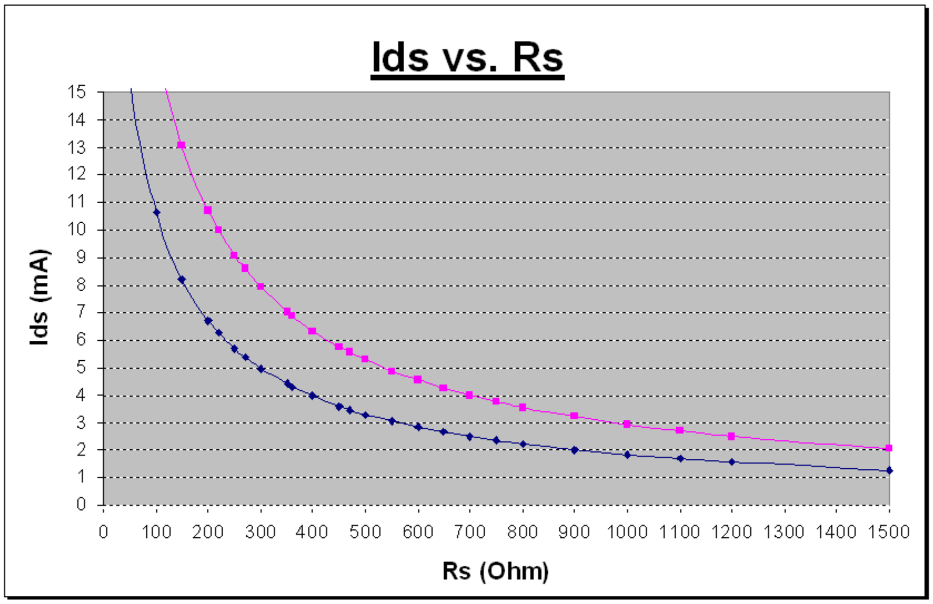


Figure 7

Other than its easier availability, previously mentioned temperature dependency of the JFETs is the reason why BF245A is now used to null the offset signal current instead of the previously used 2SK170; a 2mA is notably closer to its zero temperature coefficient point at transconductance curve and hence the voltage drift on the DAC's output is a bit lowered than it was in the previous DAC version. Also, because we need there more precisely set current, these current sources use multiturn trimmers instead of the resistors.

In all the JFET current sources used in this DAC you'll note gate resistors (gate stoppers), and they are here for the JFETs' stability.

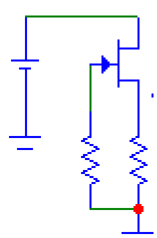


Figure 8

For those more mathematically oriented, relations from the text above can be also expressed by the following formula, but other than Idss, Vgs(off) (cut off voltage) also has to be known:

Rs = (Vgs(off)/Id) * (1-√(Id/Idss))

This formula and generally more info on JFET constant current sources you'll find in the Vishay/Siliconix' Application Note 103, "The FET Constant Current Source/Limiter". http://www.vishay.com/docs/70596/70596.pdf
There are also excellent Erno Borbely general articles on the topic of the JFETs also nicely covering issues related to the current sources, "JFETs: The New Frontier", available for download from his site.
http://www.borbelyaudio.com/special_articles.asp

c) Voltages

As previously stated, it may be trickier to set needed voltage if 3.3V oscillator is used. Other than general problem of the Zener's voltage impreciseness, the main issue is that this low voltage Zener is current dependent. Also, if VHC series flip flops supplied by 5V are used, there is no much headroom for their proper triggering (as I've said, though they will in practice do normally with 3.3V clock, this is in fact out of the specified range). The figure 9 shows this dependency for General Semiconductor's ZPD diode.

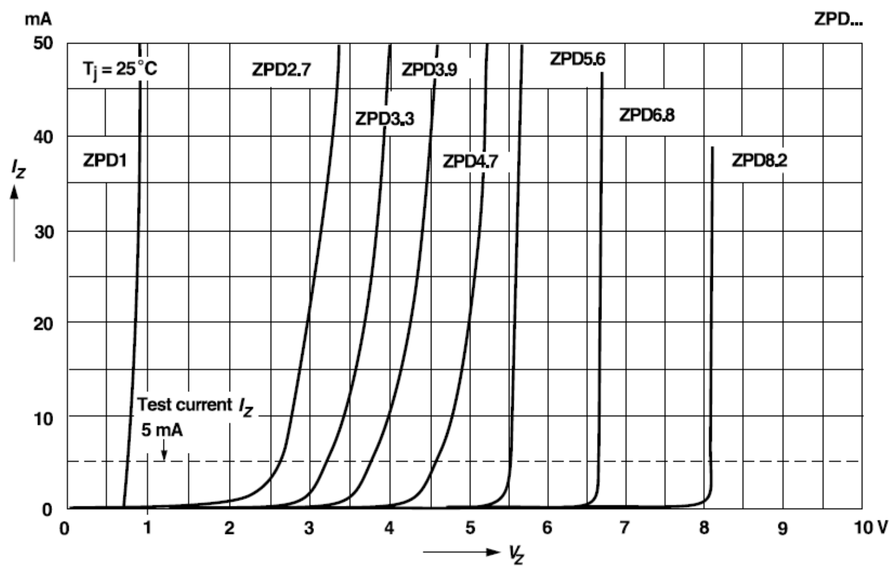


Figure 9

The graph points out the following: if voltage you've measured is lower than needed, you can make it higher running higher current through J1 (and thus through D33) and you can do this lowering the value of R4, and vice versa.

Please don't use "power diodes" since these would require much higher currents to achieve nominal voltage.

Please take note that all these regulators have thermal drift which results in certain increase of the outputs voltage during the first few minutes. <u>This drift is caused by the positive temperature coefficient of the Zener's voltage and negative temperature</u>

<u>coefficient of transistor's Vbe</u> (so increasing the temp the less voltage drops on them; Vbe tempco is approximately -2mV for each °C). The total increase on the regs' outputs anyhow shouldn't be huge i.e. not higher than 0.2-0.3V for the 5V regulators and not higher than 0.5V for the 15V regulator. The reason for this difference is that the Zeners' temperature coefficients decrease with their voltages. In case of 3.3V regulator you may actually experience slight decrease in the regulator's output voltage since Zeners below 5V have negative temperature coefficient. However, as long as you run Zeners at relatively modest currents, the voltage drifts should be modest too. The figure 10 shows temperature dependency of Vishay's BZX79 Zener diodes' voltages.

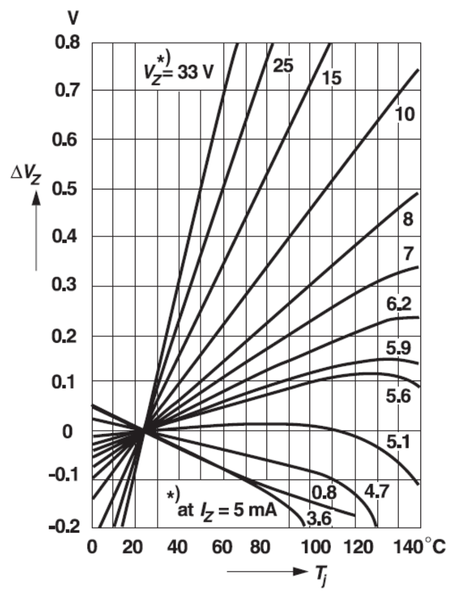


Figure 10

Let me remind you that you have to be especially careful with a current running through D37 and not let it have to dissipate the power it is not rated for (the power dissipated on Zeners is equal to their voltages multiplied by just discussed current).

<u>2.3: Constant current sourced precision shunt regulator for the flip-flops</u>

I've settled on the precise voltage regulator here to count with at least one relatively precise voltage in the I^2S reclocker setup (and thus enable use of 3.3V XO only changing XO's supply voltage). With 1k/1k (R10/R11) divider the voltage here should be pretty stable and close to 5V. For the same goal 1% resistors should be used here.

A constant current source is used in this supply to improve flip-flops regulator's PSRR and to improve decoupling between flip-flips and the oscillator. The same bipolar transistor current source is used in the output stage supply. Such a BJT current source is a textbook easy one... Referring to the components used for the CCS in the flip-flops supply, R9 supplies the voltage reference D34 which is the red LED, having about 1.65V.

The voltage drop on the Vbe of T3 is about 0.65V so we have about 1V across R8. With 47R for R8 the current is set a bit above 20mA.

As said, this current at the output of T3 is regulated down to 5V by IC1. Two flip-flops are decoupled from each other by RC filters.

2.4: Constant current sourced shunt regulator for the output stage

Regulator for the output stage was also completely changed in this revision and is now a constant current sourced shunt regulator. Employed shunt component use a feedback since AD844 used this way demands low impedance supply. The shunt element is well known TL431 with additional PNP transistor and feedback across the both. Such configuration achieves <50mOhm impedance across the audio band and also overcomes regular TL431's current capabilities (TL431 datasheets sometimes refer to this configuration as to a "high current shunt regulator"). If deemed to be necessary, this impedance may be further lowered running more current through the shunt element which is accomplished tuning the current sources, i.e. lowering the values of R36/R43 but note that the T12/T14 will in that case probably need heatsinks (see chapter "Thermal issues").

The high output impedance of the constant current source and low impedance of the shunt element form the voltage divider with high dividing ratio, above 100dB, and such power supply rejection is pretty unobtainable by (one stage) series regulator. In addition, the regulators themselves are supplied via CRC network.

Offset nulling current sources (J101/J102) are also supplied from the same regulators and are RC decoupled from the AD844's supply lines.

3. Layout

Like in the previous version, galvanically isolated supplies are also used to make possible uncompromised layout where the signals' return paths don't share the traces in between and with supply paths, and where supply paths don't share the traces in between. However, because of their numbers, this goal couldn't be fully achieved - some return paths are still partially shared – but I've tried to recognize them and to make them as short as possible.

Considering the length of the paths, this version brings noteworthy improvement in the active divider's decoupling because of use of Black Gates NX capacitors instead of the previously used WIMA MKP - this shortens their paths to the ground and, since the path (thinking about the "path" think always about both the signal and return). This also made possible shorter connection between the receiver and TDA since it previously had to surround one row of these caps. Another contributing factor in this shortening was the fact I moved to the CS8414 which is the SMD piece.

Approach to the TDA layout is now also different. I've referred the input signals to the TDA's digital ground pin but other grounds are treated like the analog ones so there is a ground plane beneath.

Is all about it then as good as I can imagine? Honestly, since I've did it in the separate board, the layout of the reclocker itself was probably better in the previous version. Now, with such circuit placed a few centimeters from everything else, including the analog stage, there were constraints... I even settled on single flip flop per line to avoid some emitting routes. It is not always possible to satisfy unusually completely opposite demands. The good and very important thing is that the routing to and back from the reclocker is now notably shorter. Ultimately two things with it may look critical. One clock's lead (HF) is close to the Zener's (D33) path to the ground (has to be quiet). The other thing is the path of the resistor R9 supplying the current to the D34. If you like, you can reroute (hardwire) these paths (referring both D33 and R9 directly to the grounds of the C2/C3), however take note that the oscillator is pretty close. Yes, a third layer would solve it...

It worth to note... Comparing to the rev1.1b I put in the board reclocker, four discrete supplies and three CCS/shunt regulators, yet the board size is still about $2dm^2$.

The bottom line is: the noise measured at the output is dominated by the asynchronous way the reclocker works. A layout related hum & noise is something I am very proud off.

One notice, essentially layout related, remains from the previous DAC project (credit goes to Gary Bronner who has pointed out this): if you don't try swapping "polarity" of the leads of the secondary supplying reclocker you may lose some important bits of it.
http://groups.yahoo.com/group/tda1541a_dac/message/5
http://groups.yahoo.com/group/tda1541a_dac/message/7

4. Assembly Tips

It is highly recommended to solder and check supplies first (it is the good idea to hook them one by one to avoid possible multiple surprises) and after you are sure all is fine with them (voltmeter is a must, oscilloscope probably won't be but is recommended) you may put the integrated circuits IC101-IC106 in. If you don't use heatsinks for T12/T14, be fast measuring output stage regulators. When AD844s are not in place, T12/T14 will have to sink all the current sourced by the T11/T13 which means they will have to dissipate about 500mW.

If you bought the board with pre fitted SMD parts the procedure should look like this:

- To check CS8414's regulators, solder only input and ground pins of IC2 and IC4 and measure the output. It is convenient to do this leaving the legs with original length. After then you just pull in the whole piece (now all the pins). However, in this case you have to make sure the regulators you use here are stable without any output capacitance. ZR78L05 are, but be warned that most of conventional "local" (TO-92 packaged) regulators are not.

- To check XO's regulator, cut the lead between T2's emitter and XO's supply pin. Scalpel is enough for this and you can easily connect it afterward by one drop of the solder.

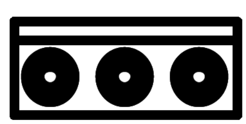
- To check flip-flops' regulator, solder all the components but R12 and R13.

Note that I/V resistors have two pads on the bottom side. One has to be used without and the other with sin(x)/x compensation.

If you are in doubt about the LEDs' pins, the shorter lead is the cathode.

To prevent surprises, please fill vias with solder. They are plated through but they are not even remotely indestructible. When you are soldering, make sure the soldering joint is good at the track side of the board.

Please, be careful with BD139/BD140 pinout. It is the same for both BD139 and 140 and is shown below (this is likely superfluous but who knows, somewhere it may save a transistor or two). Two lines show the transistor's back (a tab, if there is at all) i.e. the marking would be on the opposite side. Pins are marked for the "top view".



5. Thermal Issues

Several regulators may need heatsinks. Small TO-126 transistor designed. If you sacrifice aesthetics, a piece of aluminum will work fine too.

If a transformer from the previous DAC version is used, i.e. with 21VAC secondary winding for -15VDC line, the pass transistor (T6) of the -15V regulator will definitely need a heatsink. In that case it is also good to move C16 beneath the board and thus further from the heat and thus make it live longer. This may be anyhow needed because of the heatsink mounting screw. The result may look like on the picture below.

The rule for all the discrete regulators, i.e. their series pass transistors is: the power dissipated on them is equal to the voltage drop across them multiplied by the current drawn by the circuit they feed. The voltage drops are equal to the Vin-Vout where Vin is equal to the AC voltage of transformer's secondary feeding the particular line multiplied by 1.41 and minus the voltage drop across the rectifying diode (0.2-0.7V), and Vout is the regulated voltage at the regulator's output. As for the currents, the data can be found in the TDA1541A's datasheet (typically 27mA for +5V, 37mA for -5V and 25mA for -15V). Please add 5mA for the loading resistors. Higher frequencies oscillators draw more current than the lower freq ones. Regulating from 8VAC to 5VDC and using Crystek C3291 no heatsink is needed for T2. In my experience TO-126 packaged transistors are generally safe without heatsinks as long as the power they dissipate is not above 300mW.

The next candidates for heatsinks are T12/T14 transistors of the shunt regulators for the output stage. These transistors sink all the current sourced by the current sources T11/T13 and not used by the AD844s, TL431s and their voltage dividers, and offset nulling current sources. The calculation for the typical case says that the idle current of each AD844 is 6.5mA, TL431s draw about 3.5mA (set by Vbe of T12/T14 and R40/R47) and their dividers draw the next 2.5mA, which all sums to 19mA. The positive rail also has two 2mA offset nulling currents so it sinks 23mA. The minimum needed headroom is 5mA and it is defined by the need of each AD844 for additional somewhat more than 2mA for the full signal swing but in practice we make it to be a higher. The current of the sources T11/T13 is set by the resistors R36/R43 and is equal to the (red) LED voltage (about 1.6V) minus Vbe of the T11/T13 (about 0.6V), so it is about 1/R i.e. some 37mA for the positive and some 33mA for the negative rail. Thus we expect 14mA through T12 and T14 i.e. about 210mW typical dissipation. Due to components' tolerances, the actual values may differ somewhat.

With non-A version of TDA1541 you have to take more note on the transistors T8 and T10, regulating +/-5V supplies for the TDA since the claimed current drawn by these lines is 45mA. They will be in fact still probably fine but may heat a bit much C24. In that case you can mount this cap beneath the board. T6/T8/T10 essentially can use one heatsink but in this case C24 definitely has to go beneath the board.

TDA1541A dissipates typically 700mW (TDA1541 non-A 850mW) and it is normal for it to get warm. It will, and usually does work without heatsink, so no reason for panic but this is also the reason why it is not recommended to leave TDA1541(A) based DACs permanently powered on.

Notice:

The pictures in this document show the DAC revision 2.0. You'll note that the version 2.0c doesn't have two capacitors footprints beside T12/T14. Also, a couple of parts are marked differently. However, everything else in this document, including the Parts List and the Component Layout, in fact match the version 2.0c.

Any other contradictions in this document are unintentional, so if you encounter some please let me know as soon as possible.

6. Parts List

Semiconductors

#	qt.	designation	value	comment / alternative
1	3	IC1, IC5, IC6	TL431	
2	2	IC2, IC4	ZR78L05	alt: ZSR500, AN8005
3	1	IC3	78L05	
4	2	IC101, IC102	74VHC74M	alt: 74VHCT74M
5	1	IC103	CS8414	
6	1	IC104	TDA1541A	
7	2	IC105, IC106	AD844AN	
8	1	XO	C3291 50MHz	alt: C329x or C339x 50-125MHz
9	2	T1, T7	BC547C	any part from BC546-550 range may be fine but –C suffix is preferred
10	2	T2, T8	BD139	
11	7	T3, T6, T10, T11, T12, T13, T14	BD140	
12	3	T4, T5, T9	BC557C	any part from BC556-560 range is fine but it is better to avoid BC558/559 for T5; –B & -C suffixes are preferred
13	4	J1, J2, J3, J4	J309 or J310	in fact many JFETs will do fine here but watch the pin out
14	2	J101, J102	BF245A	
15	32	D1 – D32	1N5819	alt: BAT48, BAT49, STPS2H100...
16	3	D33, D38, D39	Zener 6V2	500mW
17	4	D34, D35, D40, D41	red LED	
18	1	D36	green LED	
19	1	D37	Zener 16V	500mW min, 1W preferable

Capacitors

#	qt.	designation	value	comment
1	6	C1, C2, C9, C12, C19, C23	1000u/16V	elco
2	1	C3	100nF	ceramic or polypropylene
3	5	C4, C11, C16, C20, C24	10u/16V	elco
4	8	C5-C8, C10, C13, C21, C25	68u/6.3V	OS-CON SP or Black Gate NX 47u/6.3V
5	2	C14, C15	1000u/35V	elco
6	1	C17	68u/20V	OS-CON SP or Black Gate Std 47u/16V
7	3	C18, C22, C26	0.1u	SMD 1206 or ceramic multilayer
8	4	C27, C28, C30, C31	2200u/35V	elco
9	2	C29, C32	47u/16V	Black Gate Std
10	6	C33-C38	22u/16V	Black Gate Std
11	14	C101, C104-C110, C112-C117	0.1u/50V	Black Gate NX
12	2	C102, C103	10p	styrene or ceramic multilayer
13	1	C104B	3.3n	SMD1206
14	2	C111, C118	0.47u/50V	Black Gate NX
15	1	C119	470p	mica or polypropylene
16	2	C120, C123	1.8n	polystyrene
17	2	C121, C124	1n	polycarbonate or polystyrene (see project rev1.1b)
18	2	C122, C125	4u7/50V	Black Gate N

Resistors

#	qt.	designation	value	power rating	notice
1	8	R1, R2, R17, R18, R34, R35, R41, R42	10R	1W	
2	15	R3, R7, R10, R11, R15, R16, R19, R24, R28, R29, R33, R39, R46, R111, R115	1k	1/4W	can be 1/8W
3	4	R4, R20, R25, R30	see text	1/4W	
4	5	R5, R9, R21, R26, R31	2k2	1/4W	can be 1/8W
5	4	R6, R22, R27, R32	300R	1/4W	
6	1	R8	47R	1/4W	
7	4	R12, R13, R48, R49	4R7	1/4W	can be 1/8W
8	5	R14, R37, R38, R44, R45	5k1	1/4W	can be 1/8W
9	1	R23	3k3	1/4W	
10	1	R36	27R	1/4W	
11	2	R40, R47	180R	1/4W	
10	1	R43	30R	1/4W	
12	5	R101, R102, R106, R107, R108	47R	1/8W	
13	2	R103, R104	150R	1/8W	carbon, see notice[1]
14	1	R105	470R		PLL resistor
15	2	R109, R110	22R	1/8W	
16	2	R112, R116	1k5	1/4W	I/V resistors
17	2	R113, R117	50R	1/4W	signal carrying resistors
18	2	R114, R118	100k	1/4W	
19	2	VR1, VR2	500R		multiturn trimmer

1 – Carbon is used for its lower inductance than metal film; however, since exact value is critical and because of higher tolerances of carbons, it is good to measure a few samples and choose the best match.

Other components

#	designation / name	component	comment
1	TR101	Scientific Conversion SC944-05	
2	TR1	80VA mains transformer	secondary windings: 5 x 8VAC, 3 x 16-18VAC, 1A each
3	F1, mains fuse & fuse holder	3A normal blow for 220V toroidal transformer as specified above	the right value will depend on the actually used transformer
4	S1	3A or higher rated mains switch	
5	mains cable, socket, plug etc		

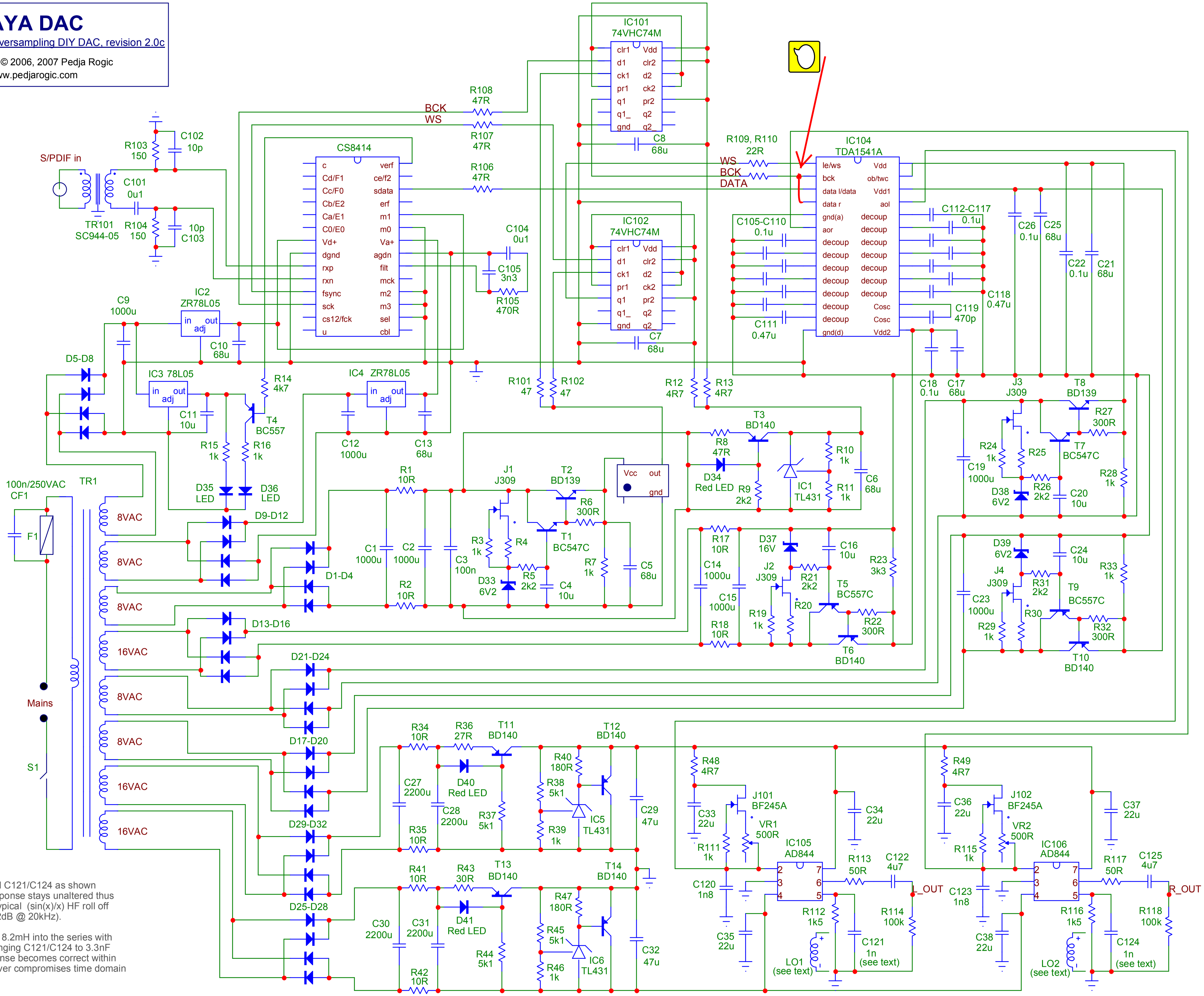
Optional components

#	designation	component / value / comment
1	RO1	termination resistor for capacitively coupled input; with transformer you may still use it for double termination
2	RO2, RO3, RO4	regularly unused footprints; may be used for a level shifting on the I^2S line or for low passing by shunt capacitors
3	LO1, LO2	small inductors / 8.2mH / the sin(x)/x compensation parts
4	CF1	100nF fuse bypass cap; has to be mains rated (X2)!!!

AYA DAC

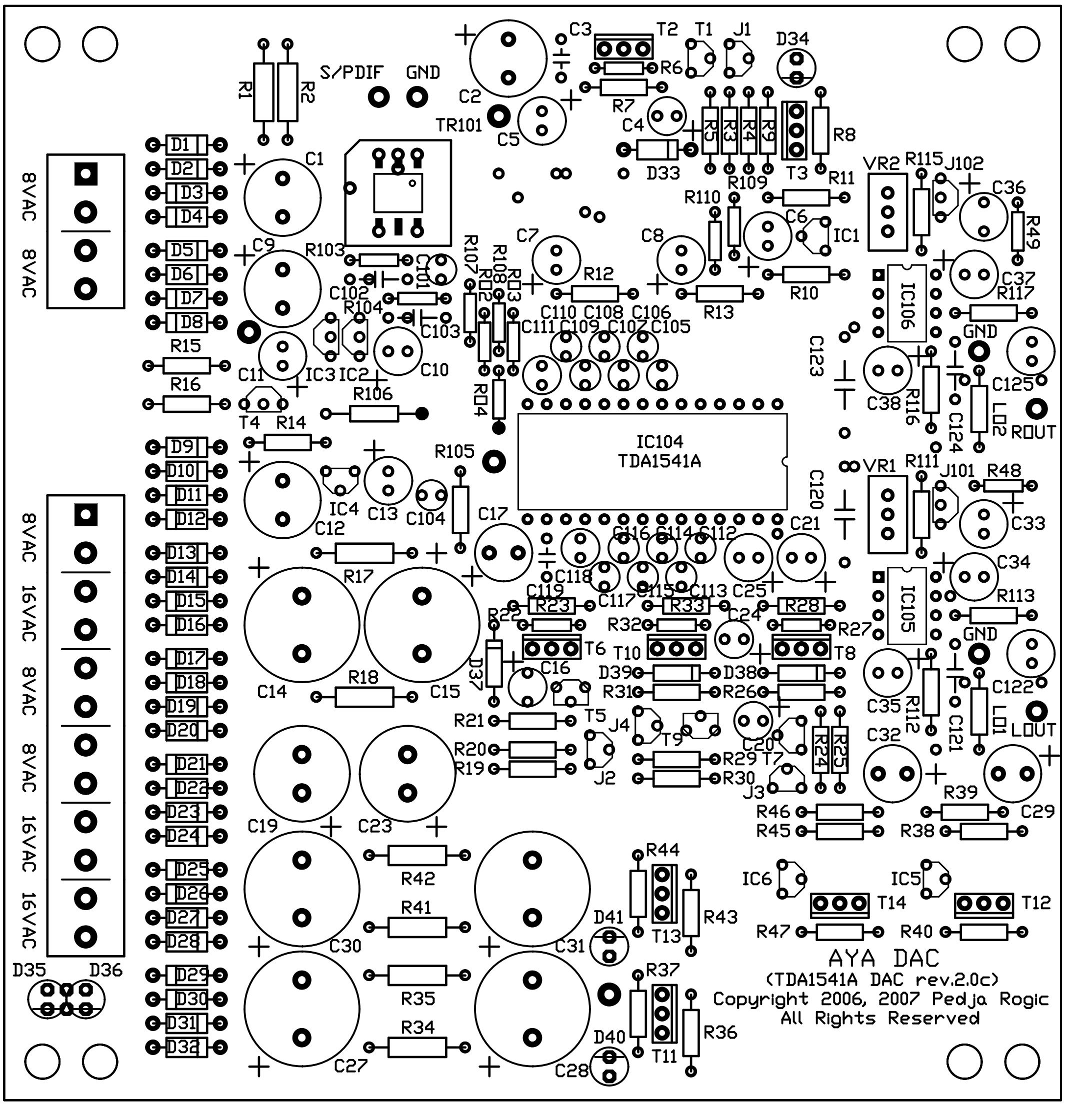
TDA1541A non-oversampling DIY DAC, revision 2.0c

Copyright © 2006, 2007 Pedja Rogic
www.pedjarogic.com



With R112/R116 and C121/C124 as shown above frequency response stays unaltered thus having for non-o/s typical (sin(x)/x) HF roll off (0.8dB @ 10kHz, 3.2dB @ 20kHz).

Inserting LO1/LO2 = 8.2mH into the series with R112/R116 and changing C121/C124 to 3.3nF the frequency response becomes correct within +/-0.2dB. This however compromises time domain impulse response.


S/PDIF
GND
8VAC
8VAC
8VAC
16VAC
8VAC
8VAC
16VAC
16VAC
IC104
TDA1541A
ROUT
LOUT
GND
GND
AYA DAC
(TDA1541A DAC rev.2.0c)
Copyright 2006, 2007 Pedja Rogic
All Rights Reserved