VCA-2180x
Dual channel Voltage Controlled Preamplifier module

In line with our Power Amplifier modules, we spent a lot of time to find the best available solution to make a volume control / buffer module as base of a High-End Preamplifier.
We believe a DSP is way too complex for many people and we also don't like the digital hocus pocus causing huge phase errors, distortion and loss of musicality. We ended at THAT Corp, providing a logarithmic Voltage Controlled Amplifier (VCA), able to set the attenuation/gain in an unbeaten range of -90/+30dB, just by feeding it a DC voltage in the range of 0-5Vdc.
Unlike the so called digital potmeter IC's, our VCA modules provide a logarithmic volume control function without extra electronics required.
On the board we added locations for an SPI controlled D/A converter too. While mounting this IC, you also can control both channels separately by SPI data.
All our VCA modules are pin compatible with this VCA-2180 line-up and all fit directly on our Preamplifier modules.

Introduction
For proper functioning of a preamplifier we need, besides a selector switch and volume control, at least some kind of amplification/buffer circuits in order to avoid impedance changes at the in- and output while changing the gain/attenuation (volume). So, why not use these amp circuits to control the gain/attenuation of the whole? A Voltage Controlled Amplifier circuit (VCA) can do this job.
Since, as with our power amps, we are not going for the cheapest but for the best, yet simplest way, we decided to use a pair of the VCA's from the THAT stable. This Blackmer® THAT2180 is available in three quality levels. We provide three different modules using different qualities of VCA's.
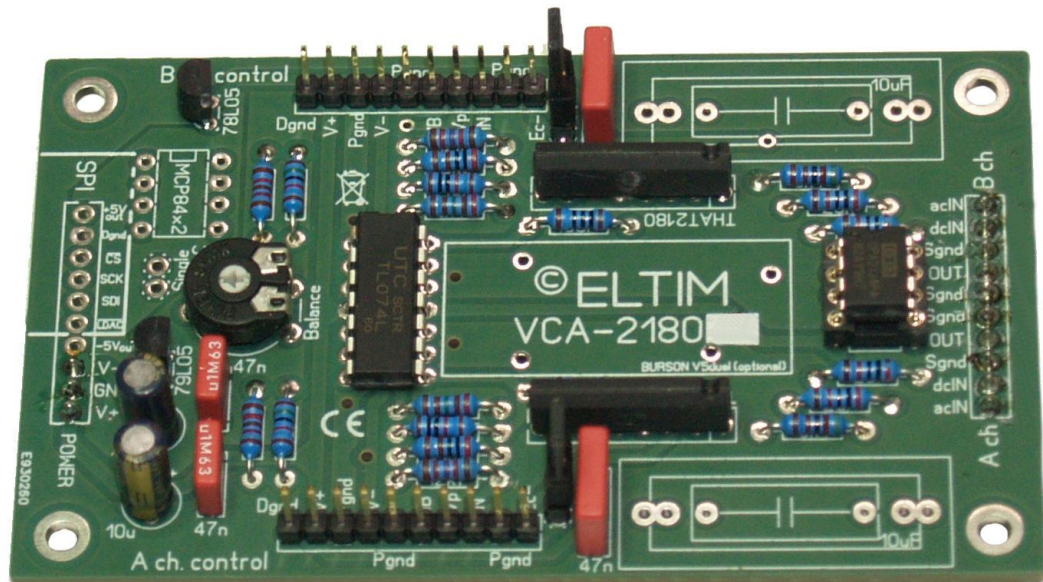They are not only setting attenuation (-90dB min.), but also providing gain up to an amazing 30dB.
We combined the VCA quality levels with the SPI controlled DAC specs in 8-, 10- and even 12 bits.
For theory of operation and specifications of the VCA, we refer to its datasheet.

Functional diagram
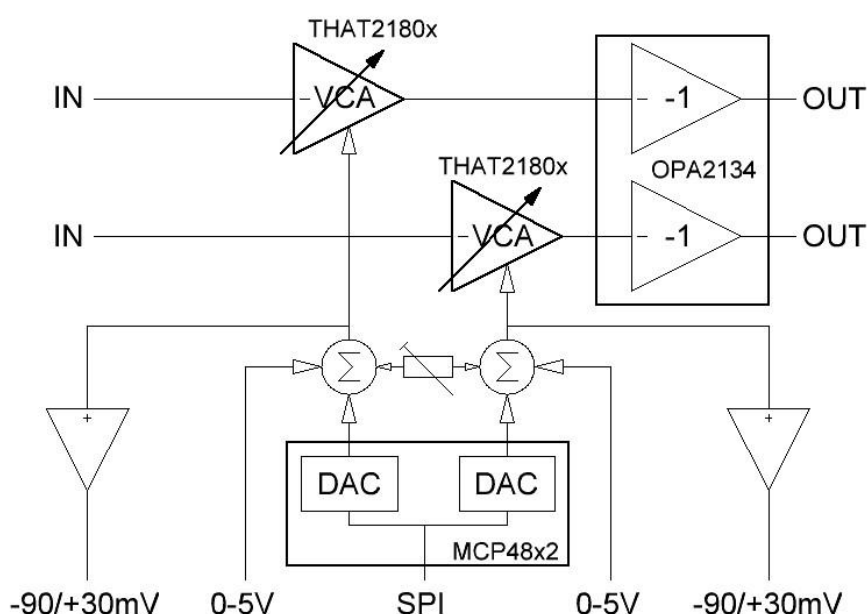
VCA-2180B, True dimensions: 60x100mm

Some features

- Extremely wide attenuation/gain control range:
  - Analogue controlled 0-4,8V: -90/+30dB, 40mV/dB, linear control curve.
  - SPI controlled DAC (option):   -90/+12,375dB, in 4096/1024/256 steps.
- Total audio circuit is processing currents, not voltages.
- Wider range and more natural feel of volume control.
- Output level can be driven up to the power rail levels, or ±11,7Vrms.
- Amazing quality THAT2180 (A/B/C) VCA circuits in SIP8 per channel.
- SMD 10uF Input ceramic (no elco's….) capacitors mounted. Larger ones fit as well.
- Larger input capacitors also fit on the board, or (mostly large) High-end types mounted elsewhere.
- There are NO in/output capacitors required if input signal is DC-free. Then use dcIN.
- Extra (DC) control port for specific functions like expander/compander/limiter, etc.
- Very low output impedance (0,01ohm) by the audiophile Burr-Brown OPA2134 dual Opamp IC.
- This Opamp IC can be exchanged by many other types, even the BURSON dual channel hybrids.
- Absolute logarithmic performance (0,5%) generated by the VCA's with linear control signal.
- Unlike with digital potmeters you can use ALL digital steps for a logarithmic scaled output signal.
- No mechanical and/or nonlinear, inductive nor capacitive components in the circuit.
- While controlling with 20MHz max. clocked, double SPI DAC, gain is limited to a practical 12dB, using maximum number of steps in logic rates (optional).
- While adding an extra analogue signal, gain of 30dB can still be reached.
- Trimmer for Left/Right balance fine trimming on board. Can be replaced by a panel potentiometer
- By changing just one control bit, range halves to -90/-30dB, with half sized steps (attenuator function).
- By changing just one control bit, the DAC goes in sleep mode (Mute function).
- The same software can be used for all three types of DAC's we use, without any extra precautions.
- +5 V regulator on board for DAC, uP and analogue (potmeter) signal. Also -5V available.
- Dual channel layout with separate VCA's in a symmetrical audio path PCB design.
- Multiple DAC's can read the same data at the same time (f.e. in balanced stereo circuits!)
- VCA-2180x models are pin compatible with our ELTIM VCA-2181x and VCA-2162 models.
- Connectors are supplied, but not mounted, so you can decide at which side they are mounted.
- All our VCA modules fit on all our Preamplifier PRE-xxx modules.

Inputs

Normally, the ACin inputs are used. In that case, a possible dc on the input lines are blocked by an 10uF SMD capacitor. You can remove them from the back side and exchange them by a 15mm, 22,5mm or even 27,5 mm pitch capacitor. Serious ones can be mounted elsewhere.

If you are sure that there is no DC signal on the input lines, you can bypass these on-board capacitors by using the DCin pins. You can also use these DCin connections if you decide to use (mostly large) audiophile input capacitors. Anyway, while using the DCin lines, the already mounted caps are **not** used!

Analogue control

As the name already tells, the attenuation/gain of a VCA is adjustable by a voltage. So, without difficult extra electronics we simply can feed a DC voltage and set the attenuation/amplification that way.

Since our ears react in a logarithmic way, a conversion from linear to a logarithmic function is required for volume control, and is performed by the VCA's in optima forma from -90 up to +30dB (0,5%):

Vertical: LOGARITHMIC Attenuation/gain scale.   Horizontal: LINEAR VCA control voltage
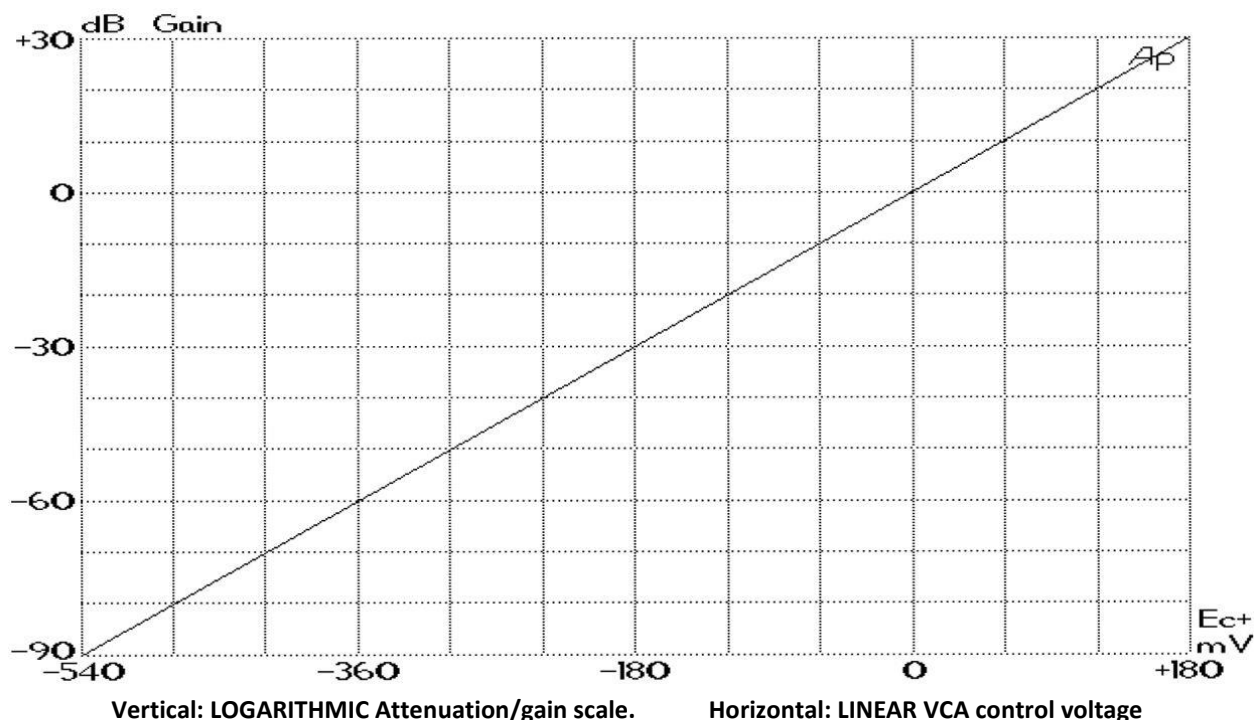
By feeding a negative voltage to the EC+ input, gain is set at -90dB if nothing else is connected.

On these VCA-2180x modules, volumes (or better: attenuation/gain) of both channels are set separately by 0-4,8Vdc LINEAR control signals, f.e. coming from a regular, mechanical LINEAR potentiometer or a digital version of it. Unlike direct use of a digital potmeter (with nonlinearity and significant distortion while processing direct audio!) as volume control, in this case ALL steps of this digital potmeter would generate a logarithmic gain step! If you like the sound of it, you also could use our RP-relay board having the required LINEAR function in 256 steps. (0,4dB/step). In this function the RP-module (or any other device) is only leading DC voltage, not any audio signal!

Even a nicer way is the use of the (optional) built-in 2-channel SPI controlled DAC's, each controlling one channel. They work separately, but also together with an analog control signal, since all three control signals (-90dB preset, analog in and SPI in) are summed and converted into a single control voltage for the VCA's by two Opamps into the -540 <> +180mV range required for the VCA's.

A simple 1/6 buffer provides a -90/+30mV signal, representing the attenuation/gain setting.
Just by connecting a cheap 200mV digital readout, you could present the actual dB setting.
You could also feed it to some uP based electronics processing it and give a readout.

Balance/ Input level correction

With a precision system like this, due to slight tolerances of components used, there will always be a small error in linearity between both channels. We solved this by adding a 240º trim potmeter, feeding more or less balance DC voltage to both VCA circuits. This way, you can balance both VCA's exactly. We use the -90dB control voltage to do this job. This trimmer only leading dc signals, so no shielding required nor signal quality losses for optional panel mounted balance potentiometers.

Similar, you can change one or both bitwords in the DAC's in order to provide a balance control.

Especially with the A type with 4096 steps of 0,025dB, you could make a reference table in your software, where left and right channel are matched in a linearity of both channels in a ridiculous 0,025dB resolution.

Output Amplifier

Since the VCA's we use invert the audio signal by 180º, inverting circuits are necessary in order to convert the CURRENT output signals of the VCA's into 0º voltages again. For this we use high quality Opamps.
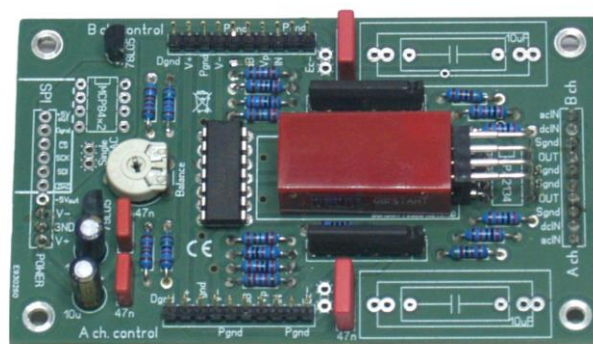
The output impedance and behaviour of these OpAmps largely defines the total performance.

In the three available models of the VCA-2180 we have, we use different qualities of THAT 2180's and different output buffer IC's.

The C- type is fitted with TI NE5532, commonly used in better HiFi and some High-End equipment.
The B-type is our most sold model, using an audiophile Burr Brown OPA2134, one of the most respected dual opamps in the audio community and used in about all kinds of high quality audio gear like expensive mixing units. Anyway, most sure your recording passed a few of these while registering it for the future.

ELTIM VCA-2180A with mounted Burson V6 dual opamp

The famous BURSON V6 dual Opamp is mounted on our A-model, also having spectacular low distortion figures. It can be mounted vertical or horizontal as shown in the picture, saving vertical space. Besides the I/U conversion, we also follow the custom and unwritten rule that any audio circuit should not invert the signal by using these inverting OpAmps, since the VCA outputs are also inverted. 2x180º=360º=0º.

Display

While controlling this VCA module by a uP, this uP knows what setting is given and can display that values. For analogue controlled setups you could use cheap and general available 200mV voltmeter readouts.

For displaying the value with 199,9mV display modules, we also provided an output per channel, giving exactly the dB level in mV, so from -90,0/+30,0mV, sorry dB -).   Just connect a pair (or only one) of universal display modules and get a true dB reading. This (divided by 6 and buffered) signal is coming from the VCA control line, so also working while controlling by SPI. It is also a help feature for you to control if you programmed correct and /or balance both channels, just connect a voltmeter. Did you know that originally opamps were invented to calculate as analogue computers? Nobody ever heard about "digital" back then.

Since we are technical fossils as well, we know how to use them and do so. We use them for dividing, adding and subtracting voltages obtaining the resulting values we desire. Even F16's flight control systems before 2000 we working that way. We know, since we serviced them in those days.

Since the VCA's have a tolerance of 0,5% in scaling, you hardly can't get any closer, except by our VCA-2181x You also could use this analogue output signal as feedback to your uP or some other device.

Other options

Since the attenuation/gain can be controlled by voltages on two different and complimentary inputs, you could connect other electronics to control this gain.

For example, beside functioning as explained above, you could also build in a limiter function, where only a handful of electronic parts can take care that the maximum output level does not exceed a certain level.

The opposite (or even both) will work too, small signals can be amplified automatically till a certain minimum level. For details, check the VCA datasheet and THAT application notes.

Digital, SPI or I2S control (optional)

With the popularity of Arduino, Raspberry Pi and many other small and cheap uP-systems, we believed we needed to provide a digital control input as well. Doing so, new applications open for your Arduino, etc. like use in an amplifier system to control and display the volume, etc.

With adding an SPI controlled DAC, volume can be set in 4096 (0,025dB) steps with a MCP4822 mounted. *(0,0125db/step in half rate mode).* Also MCP4812 (1024 steps) and MCP4802 (256 steps) fit.
Present the dB value on your Arduino display screen. There are similar pin-compatible I2S DAC's available as well. We do not mount a DAC IC on our modules!

So, unlike with digital Potmeter IC's and most relay attenuators, <u>every bit step is a true logarithmic step</u>! Programming becomes most simple this way, since you don't need to make a logarithmic response table. Just step up/down by one, or more for fast jumping.

DAC programming

All three possible SPI DAC types we mentioned above are pin- and programming compatible where lower bitrate DAC's just ignore the last bits of a possible 12-bit data word in the total of 16 bits, where last 12 (or 10 or 8) are used as data bits:

REGISTER 5-1: WRITE COMMAND REGISTER FOR MCP4822 (12-BIT DAC)

W-x	W-x	W-x	W-0	W-x	W-x	W-x	W-x	W-x	W-x	W-x	W-x	W-x	W-x	W-x	W-x
A̅/B	—	GA	SHDN	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
bit 15															bit 0

REGISTER 5-2: WRITE COMMAND REGISTER FOR MCP4812 (10-BIT DAC)

W-x	W-x	W-x	W-0	W-x	W-x	W-x	W-x	W-x	W-x	W-x	W-x	W-x	W-x	W-x	W-x
A̅/B	—	GA	SHDN	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0	x	x
bit 15															bit 0

REGISTER 5-3: WRITE COMMAND REGISTER FOR MCP4802 (8-BIT DAC)

W-x	W-x	W-x	W-0	W-x	W-x	W-x	W-x	W-x	W-x	W-x	W-x	W-x	W-x	W-x	W-x
A̅/B	—	GA	SHDN	D7	D6	D5	D4	D3	D2	D1	D0	x	x	x	x
bit 15															bit 0

Where:

bit 15   **A̅/B:** DAC_A or DAC_B Selection bit
   1 = Write to DAC_B
   0 = Write to DAC_A

bit 14   **—** Don't Care

bit 13   **GA:** Output Gain Selection bit
   1 = 1x ($V_{OUT} = V_{REF} * D/4096$)
   0 = 2x ($V_{OUT} = 2 * V_{REF} * D/4096$), where internal $V_{REF} = 2.048V$.

bit 12   **SHDN:** Output Shutdown Control bit
   1 = Active mode operation. V_{OUT} is available.
   0 = Shutdown the selected DAC channel. Analog output is not available at the channel that was shut down. V_{OUT} pin is connected to 500 kΩ (typical).

bit 11-0   **D11:D0:** DAC Input Data bits. Bit x is ignored.

Of course, a 10 bit DAC can work with total 14 bits as an 8-bit DAC can with 12 bits total.
As listed above, if more bits are received (f.e. all 16 bits for an 8-bit DAC) redundant bits are ignored.
So, best is to write your software in 16 bits structure; then you can choose any of our VCA modules you like.

The 2-channel DAC is controlling both VCA channels separately and need to be programmed separately as well. Data will only be accepted while the CS pin is low. Only after data is latched, the DAC and the output amplifier will come alive. Till that time the output pin of the DAC is internally grounded by a 500kohm resistor.

Check out bit 13; by setting it to "1", the output voltage is reduced by 50%, useful as gain attenuator switch, reducing the gain of the module between -90db and -30dB in half of the original step size.

With bit 12 you could mute the system, leaving the latched data untouched. It's meant to power down the DAC and output amplifier in order to save some energy though. No voltage to the VCA's causes -90dB attn.

A hardwired pin at the DAC-chip enables you to load data first in multiple DAC's (taking time) and then ground the LDAC pin. Then all the internally latched data of all DAC's in your system are activated at exactly the same time (f.e. after power up). This possibility is recommended in these VCA-2180 modules in order to let both channels step exactly at the same time. We also advise to use this feature while using our VCA modules in multi DAC systems like mixing consoles, balanced circuits, etc.

www.eltim.eu

Extra Gain in SPI mode

In order to get logical, "rounded" steps from the DAC's, the VCA's are only used for a gain up to +12dB, way enough for regular High-End use. However, the VCA's still have 18dB headroom to spare. While, beside some DAC setting, adding a DC-voltage, you can rise the workspace of the VCA's from -90/+12dB to -72/+30dB in a rate of 40mV/dB. You also can use this way for balance control or other correcting functions.

Extra gain control port "ec-"

With our November 2016 update, we managed to feed the extra (ec-) control ports of both VCA's to the side connectors. Normally, a jumper connects them to ground, where this board is func-tioning as described and VCA function is done by the ec+ connection internally. Ec- pin is connected to ground via a jumper then.

Since ec- works exactly complimentary to ec+, we refer to the ec+ info written in former pages.
For detailed information check the THAT 2180x datasheet.
While using the extra ec- port, a lot of volume controlling options become possible, like musical effects (tremolo, vibrato, etc.), limiter- and expander functions. Also, you could shift the working range by 18dB as shown in the graph above.
We can also imagine a circuit taking action if the output signal of a power amplifier comes close to the voltage rail limits and starts "clipping". Just before that point you amp could take back some volume automatically.
If our VCA modules become a hit, we will do some experiments with these kind of circuits.
In the meantime you can find a lot of extra circuits in the THAT design notes.
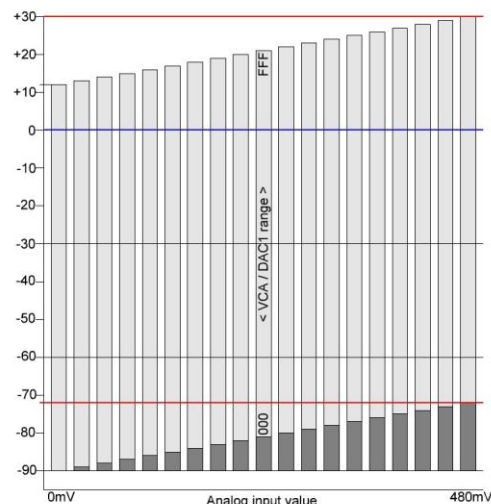
VCA-2180 model range

We have three models, where just the quality of the VCA IC differ:

Models:	VCA-2180A	VCA-2180B	VCA-2180C
VCA-type:	2x THAT2180A	2x THAT2180B	2x THAT2180C
THD@1kHz@0dB:	0,005%	0,01%	0,05%
Output buffer:	BURSON V6	OPA2134	NE5532

Optional SPI control function (IC is not mounted!):

DAC-type (SPI):	MCP4822 / MCP4812 / MCP4802 *or similar*
DAC-bitrate:	2x 12 bits / 2x 10 bits / 2x 8 bits
SPI-steps:	4096 / 1024 / 256
SPI step rate:	0,025dB / 0,1dB / 0,4dB, *no log/lin step map required as with digital potmeters*

General technical data:

Max. attenuation:	-90dB
Max. gain:	+30dB
Channel separation:	>110dB
Frequency range:	DC – >300kHz (limited by us)
Slew rate:	12V/uS
Output swing:	±14V max (Vsupply-1V).
Output noise:	-98dBV@0dB gain
Gain linearity:	0,5% typical, 2% max.
Power supply:	± 8-18V, 10mA

This design is copyrighted
by ELTIM audio BV
Louis Timmers 2020 ©
PE1LTM

www.eltim.eu

ELTIM *AUDIO*

IN

OUT

L R

R L

Vpm

Balance

Volume

IN b

IN a

gnd

P P P P

B ch

A ch

acIN dcIN Sgnd OUT Sgnd Sgnd OUT Sgnd dcIN acIN

10uF

10uF

5k1 20k 20k

OPA2134

20k 20k 5k1

THAT2180

THAT2180

© ELTIM
VCA-2180

BURSON V5dual (optional)

47n

47n

100R

100R

Ec- Ec-

P

P

Pgnd

Pgnd

Pgnd

Pgnd

IN Vp dB

12k7 2k0 10k 2k15

2k15 10k 2k0 12k7

IN Vp dB

V- Pgnd V+ Dgnd

V- Pgnd V+ Dgnd

TL074

15K 12K1

15K 12K1

Balance

5k

B ch. control

78L05

MCP84×2

Single DAC

79L05

10u 10u

A ch. control

47n 47n

SPI

+5V Dgnd CS SCK SDI LDAC

-5Vout V- GND V+

POWER

SPI

-15V GND +15V

3 1/2 Digit display module

(Left channel) dB value

3 1/2 Digit display module

(Left channel) dB value