Dual VCA

Kassutronics

Board revision 1.1, documentation revision A

January 11, 2019

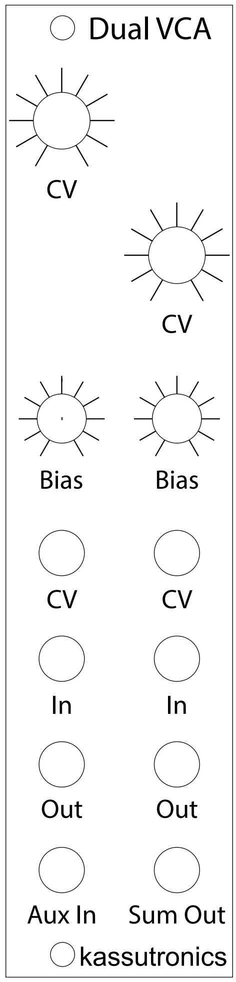
Description

You can never have enough VCAs, a common meme in modular synthesis declares. While this module certainly cannot fill that infinite gap, it does add two handy voltage controlled amplifiers to your setup.

These linear, DC coupled VCAs are suitable for both audio and CV processing. The control inputs have dedicated attenuators, and each VCA can be manually opened with the Bias control.

Finally, the module has a built-in mixer, summing the output of both VCAs and one auxiliary input into the Sum Out jack. This way, for example, multiple units can be daisy-chained to form a multichannel voltage controlled mixer.

The module is built around the AS3360 dual VCA chip, a clone of the CEM3360 (the latter should also work in this module, but has not been tested). Except for the AS3360 itself (which is in a PDIP package), the board uses 0805 SMD parts and SOIC opamps.



Front panel

Features

- Two independent VCAs
- Linear control scale
- CV attenuator controls
- Bias controls add an offset to the CV
- 6hp Eurorack format

Recommended operating conditions

Symbol	Parameter	Recommended	Maximum	Unit
V_{CC}	Positive rail voltage	+12	+14	V
V_{EE}	Negative rail voltage	−12	−14	V

Note: The maximum supply voltages are set by the AS3360 absolute maximum limits. This module can *not* be operated directly on ±15 V supplies.

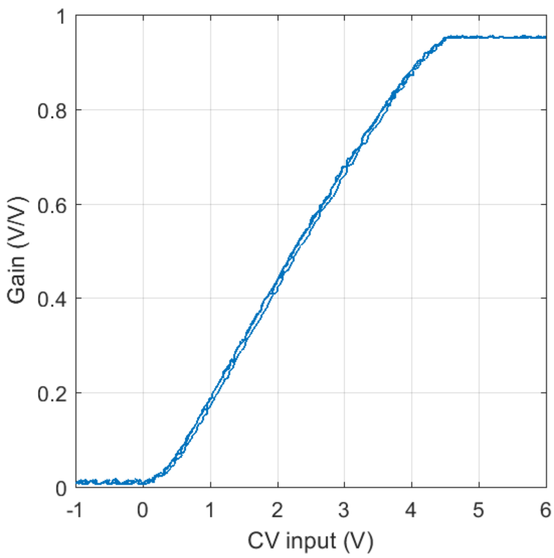
Typical performance characteristics

Typical characteristics measured from a prototype and not guaranteed.
$V_{CC} = 12V$, $V_{EE} = -12V$

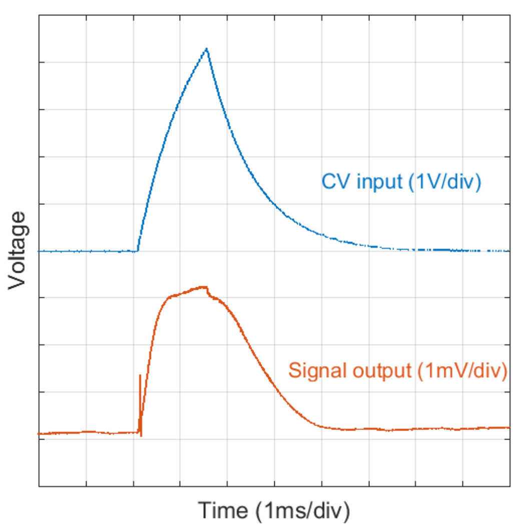
Symbol	Parameter	Typical value	Unit
I_{CC}	Current consumption, +12V rail[1]	20	mA
I_{EE}	Current consumption, −12V rail[1]	19	mA
	VCA signal path		
Z_{in}	Input impedance, signal input	51	kΩ
$A_{V,max}$	Maximum gain[2]	±1	dB
$A_{V,min}$	Maximum attenuation[2]	−75	dB
	Control-voltage feedthrough[2]	−60	dB
	Channel-to-channel crosstalk[2]	< -90	dB
THD	Total harmonic distortion[2]	0.6	%
BW	Signal bandwidth	> 100	kHz
	Output offset voltage	40	mV
	VCA control input		
Z_{in}	Input impedance, CV input	34 – 100	kΩ
	Control voltage for maximum gain	4.4	V
BW	Control input bandwidth	22	kHz
	Unity-gain mixer		
Z_{in}	Input impedance, Aux In	100	kΩ
BW	Signal bandwidth	22	kHz

[1] Current consumption can be significantly higher when the outputs are loaded.
[2] 1 kHz, 10 V_{pp} sine wave

Linear control scale
CV attenuator fully CW



CV feedthrough
No signal input



Build instructions

Component selection

The board uses SMD resistors (1% tolerance) and capacitors in 0805 size. Capacitors can be of the X7R or C0G dielectric (the latter is usually only found in smaller values), and should be rated for at least 25V.

The diodes D1 through D4 should ideally be Schottky diodes, but a normal silicon diode (4148, BAS16) is also acceptable. Continuous current rating should be 100mA or greater. The pads are designed to fit SOD-323, SOD-323F, SOD-123 or SOD-123F packages.

Note that the AS3340 must be in through-hole DIP package.

As eurorack power connector will fit either a standard 2.54mm pitch 10-pin header, or a keyed (shrouded) header if preferred.

Potentiometers RV1 and RV2 should be of the metal shaft type with front panel mounting thread, such as Alpha RD901F-40-15R1-B100K. Potentiometers RV3 and RV4 should be the smaller plastic-shaft type, such as Alpha RV09AF-40-20K-B10K.

Building

First all SMD parts must be soldered, then the power header and 10uF capacitors (these are all on the backside of the board), and finally the IC, jacks and pots on the front side.

Carefully check component orientation before soldering. Orientation hints:

1. For SMD ICs pin 1 is marked on the silkscreen with a circle inside the component, and an extended line next to the solder pad. On the chip itself markings may vary, but pin 1 is always in the bottom left corner when the text is in normal reading orientation.

2. SMD diodes are marked with a tiny diode symbol inside the silkscreen, and a line that goes around the negative ("cathode," if you must) side. The diode itself normally has a white line on the negative side.

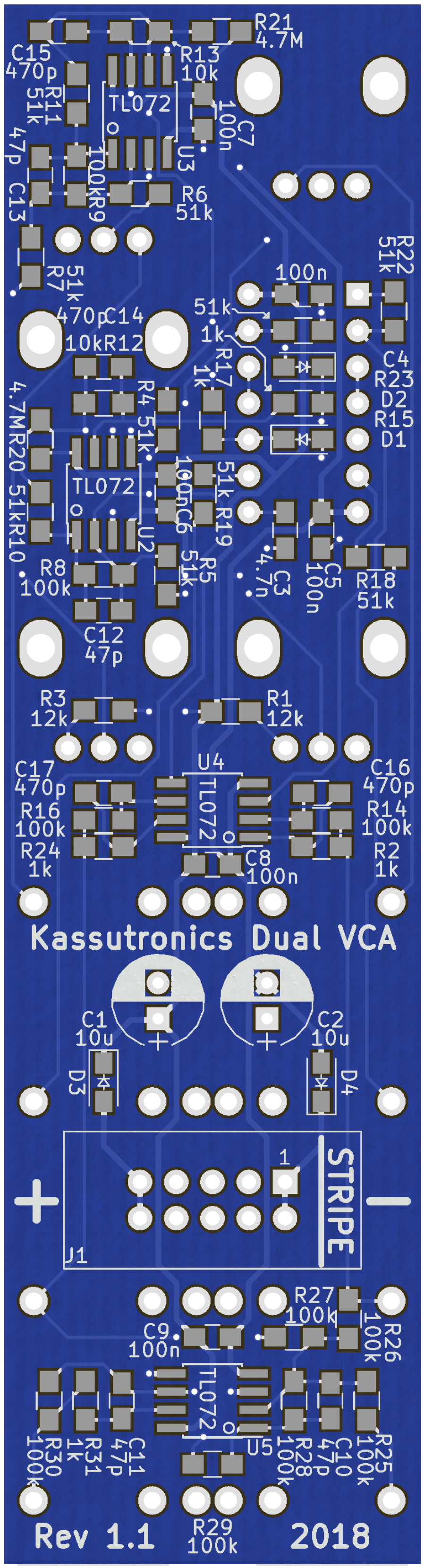
3. For electrolytic capacitors the negative side is marked by a white filled area on the silkscreen, and the positive side with a + symbol. On the capacitor itself a white band marks the negatives side, and the positive lead is longer.

Bill of materials

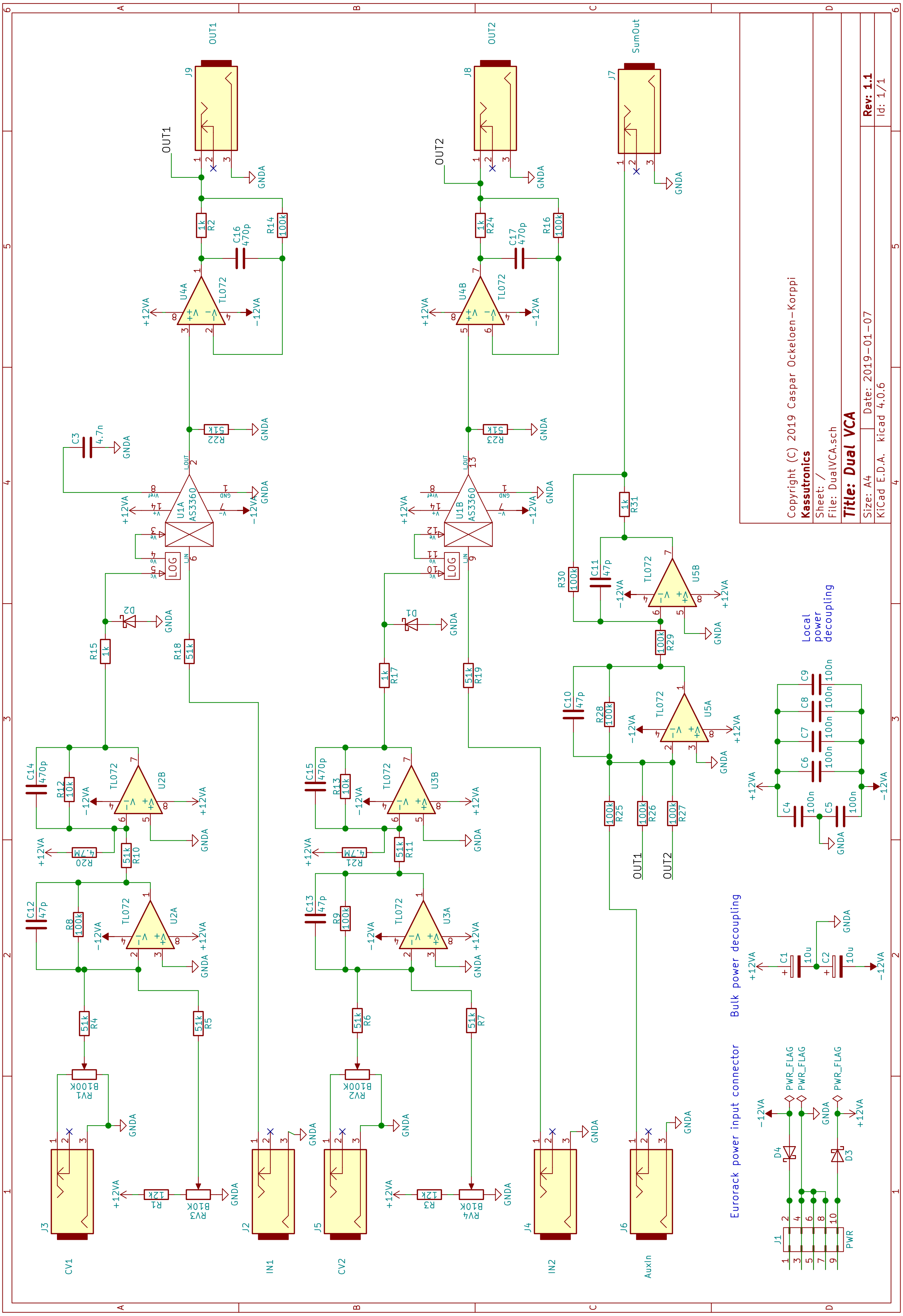
Qty	Designator	Value	Note
5	R2, R15, R17, R24, R31	1k	0805 SMD
2	R12, R13	10k	0805 SMD
2	R1, R3	12k	0805 SMD
10	R4, R5, R6, R7, R10, R11, R18, R19, R22, R23	51k	0805 SMD
10	R8, R9, R14, R16, R25, R26, R27, R28, R29, R30	100k	0805 SMD
2	R20, R21	4.7M	0805 SMD
4	C10, C11, C12, C13	47p	0805 SMD, X7R or C0G
4	C14, C15, C16, C17	470p	0805 SMD, X7R or C0G
1	C3	4.7n	0805 SMD, X7R or C0G
6	C4, C5, C6, C7, C8, C9	100n	0805 SMD, X7R
2	C1, C2	10u	min 25V, diameter 6.3mm, pitch 2.5mm, e.g. Nichicon UST1H100MDD
4	D1, D2, D3, D4		Schottky SOD-323 or SOD-123, e.g. BAT54J
1	J1		2x5 pin header, 2.54mm pitch
8	J2, J3, J4, J5, J6, J7, J8, J9		Thonkiconn jack (PJ398SM or PJ301M-12)
2	RV1, RV2	B100K	Alpha 9mm, metal shaft
2	RV3, RV4	B10K	Alpha 9mm, small plastic shaft
1	U1	AS3360	DIP-14
4	U2, U3, U4, U5	TL072	SOIC-8

Board view

Front view



Back view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Kassutronics
Sheet: /
File: DualVCA.sch
Title: Dual VCA
Size: A4
Date: 2019-01-07
Rev: 1.1
KiCad E.D.A. kicad 4.0.6
Id: 1/1
Local power decoupling
Bulk power decoupling
Eurorack power input connector
CV1
IN1
CV2
IN2
AuxIn
OUT1
OUT2
SumOut

Circuit description

The CEM/AS3360 is an easy-to-use VCA chip, and requires few external components for basic operation. However, like the other CEM chips, it was originally designed to be integrated in "normal" analog (poly)synths. In a modular synth, where the inputs and outputs are exposed directly to the outside world, some external scaling and protection circuitry is needed.

VCA core

Let's first describe the basic configuration of VCA channel 1 (channel 2 is identical). The VCA itself, U1A, is a current-in, current-out amplifier. The input signal voltage is converted to a current by R18, and the output current is converted back to a voltage by R22. Choosing these of equal value gives the VCA a nominal voltage gain of 1. The value of 51k is chosen such that a standard ±5 V modular signal has a peak current of 100μA, which I found to be a good trade-off between signal-to-noise ratio and distortion. The AS3360 can handle at least 300μA of signal current, so there is plenty of headroom at the input side (±15 V min.), however the output swing is limited to around ±10V. The output signal is buffered by U4A, which is a unity-gain buffer. The network R2, R14 and C16 allows the opamp to handle significant capacitive load arising from long patch cables[1].

The VCA core itself has an exponential control scale (pin 3). The chip however includes a log converter (pins 5 and 4), which accepts a linear control voltage between 0 and 1.7 V (nominal) and generates the appropriate exponential voltage for the VCA. The VCA block further includes power supply connections (with decoupling capacitors drawn at the bottom of the schematic) and a decoupling capacitor on the internal reference voltage generated by the VCA on pin 8. This reference voltage is not used in the external circuitry, but is used internally by the log and exponential converters.

CV signal conditioning

The module is designed to accept a useful CV range from 0 V to 4.5 V (with fully opened CV attenuator), which must be scaled to the 0 V to 1.7 V range expected by the AS3360. The incoming CV must therefore by attenuated with a gain of $1.7/4.5 = 0.38$. The module must also safely accept any voltage in the ±12 V eurorack power supply voltage, whereas the AS3360 absolute maximum rating for CV is −2 V to +2.5 V.

The required scaling and clipping is performed by two inverting opamp stages, U2A and U2B. U2A first sums the external CV with the bias voltage set by RV3, and *amplifies* it by a factor −1.96. The output of U2A is clipped to ≈ ±10 V, which corresponds to a CV input range of ±5 V. U2B then attenuates the CV by a factor −5.1, giving the required overall gain of $-1.96/-5.1 = 0.38$. Thanks to the clipping action of U2A, overvoltage on the CV input is limited ±2 V at the output of U2B. R15 and D2 further clip the negative part of this range, keeping the voltage well within the AS3360 absolute maximum spec.

For good measure, the two CV processing stages both include a roll-off capacitor limiting high-frequency CV signals. The CV bandwidth (3 dB attenuation) after both stages is 22 kHz, fast enough for audio-rate modulation.

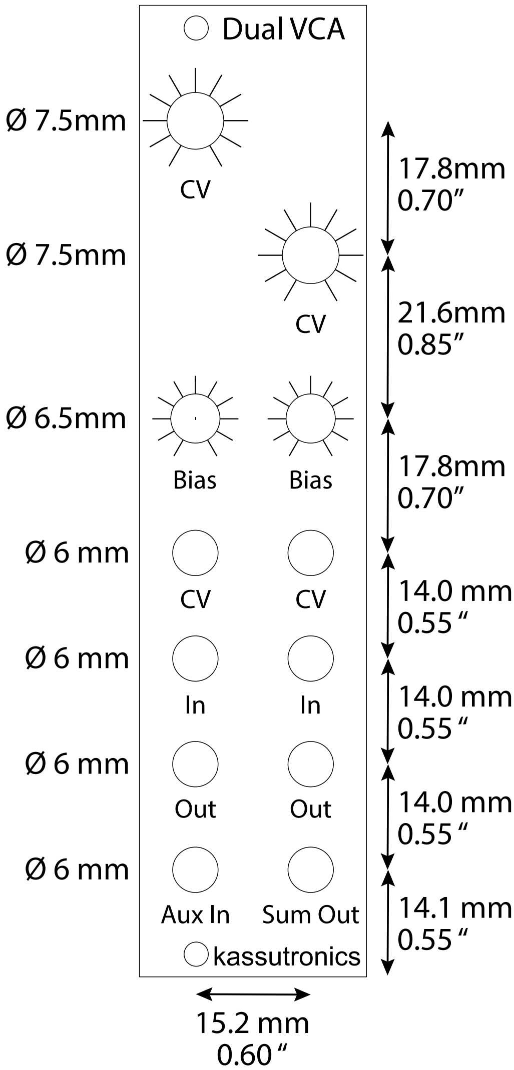
R20 gives the control voltage a slight negative bias of ≈ 25 mV. In testing, I found this helps to ensure the AS3360 turns off completely.

Mixer section

U5A and U5B form a standard mixer with unity gain. U5A sums and inverts the two VCA output signals and an external (Aux In) signal together, and U5B inverts them again to restore normal polarity. Using C10 and C11 the mixer is band-limited to 22 kHz, and U2B has a series output resistor R31 in the feedback loop to isolate the opamp from capacitive load[2].

[1] The values are tuned to allow around 500 pF load without overshoot, and up to 5 nF with some ringing. For comparison, in my tests a 1 m patch cable had around 200 pF of capacitance
[2] While the circuit around U5B looks very similar to that around U4A, their topology is quite different. U4A is used as non-inverting buffer, and a relatively large capacitance (C16) can be used without reducing the bandwidth. To function correctly, the value of C16 must be of similar magnitude as the expected load capacitance. U5B, on the other hand, is an inverting amplifier, and the capacitor C11 reduces the high-frequency gain to 0. Therefore, it must be chosen in relation to R30 to set the desired circuit bandwidth, leading to a much smaller value than C16. Nevertheless, this band limiting has a very similar end result and the output of U5B can drive similar capacitive loads up to several nF without excessive ringing

Front panel dimensions



Differences with Rev 1.0

The following table lists component values that were changed between PCB rev. 1.0 and 1.1. These changes are not critical, but I recommend using the Rev 1.1 values if possible.

Designators	Rev 1.0	Rev 1.1
R1, R3	15k	12k
C12, C13	100p	47p
C14, C15	1n	470p
C16, C17	100p	470p

On PCB rev 1.0, the silkscreen text for C17, R16 and R24 is unreadable (placed on top of the components). See the rev 1.1 board render on page 5 for their correct placement.

Revision history

Board revisions

1.0 Initial design.

1.1 Adjusted component values, fixed silkscreen errors.

Documentation revisions

A Initial documentation for board revision 1.1.

Contact

Check for updated documentation and other information on my blog at kassu2000.blogspot.com. I am always happy to answer questions and receive feedback at kassutronics@gmail.com.