Analog Metropolis

AM4023
ARP Voltage Controlled
12dB Low Pass Filter

Project Notes
V1.2

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1 Module Description

The AM4023 is a clone of the ARP 4023 2-pole 12dB low pass filter in the ARP Odyssey. This filter has a very smooth behavior and unlike most 4-pole filters, it does not attenuate the low end with increased resonance settings. Also, with a shallower cutoff slope, it could be argued that the Odyssey had a brighter sound overall. The filter is good for bass and bright lead sounds, and with modern components it is not noisy. It will self-oscillate at high Q settings and it can shred speakers – so beware!

With so many 4-pole filters around, it's nice to have a 2-pole version for some contrast.

The control inputs are accurately calibrated to 1V/octave, and there are two CV inputs which have front panel attenuators (FM1 and FM2). There is also an un-attenuated CV in for direct connection to a keyboard CV.

The filter frequency has two front panel controls; FREQ for coarse adjustment and FINE for fine adjustment, there is also an on-board trimmer to set the initial cut-off frequency.

The filter has a Q control (RESO) to adjust the resonance of the filter. Higher settings of the Q control will take the filter into sine wave oscillation.

The filter has been designed for improved modern Op Amps rather than the original LM301's. You can use LM301's but you'll need to kludge in a 3.3pF ceramic capacitor across pins 1 and 8. I recommend using modern Op Amps as the extra cost is a fraction of the total module price.

INPUTS AUDIO SIGNALS: SIGNALA, SIGNALB, SIGNALC
CONTROL VOLTAGES: CV1, CV2

OUTPUTS AUDIO SIGNAL

POTS SIGNAL A LEVEL, SIGNAL B LEVEL, SIGNAL C LEVEL
FREQUENCY, FINE, RESONANCE
CV1, CV2

SWITCH An optional 2-way centre off for selecting a control CV from a keyboard or sequencer

DISPLAY An optional 10 bar LED indicator which shows audio output level

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2 The Original Circuit

The original ARP design dates back to 1972 and the creation of the Odyssey monophonic analog synthesizer. It's a 12dB voltage controlled low pass filter, and it was used in the original "white faced" ARP Odyssey as well as some of the "black faced" models up until 1975.

It is a 2-pole OTA design based around transistors, the CA3080 (OTA) and the LM301 Op Amp. The exponential converters use matched and thermally coupled PNP/NPN pairs. The filter will self-oscillate at higher Q settings and it is temperature compensated with a 1K87 3500ppm Tempco resistor.

The design is a departure from the previous "Moog like" ARP 4006 and 4012 transistor ladder filters, probably as a response to patent infringements.

3 The AM Circuit

The Analog Metropolis circuit is an exact replica, as all parts are still available, although the CA3080 is no longer manufactured; stock still exists at some specialist suppliers.

The CA3080 OTA's are retained, modern 2N3904 and 2N3906 transistors are used instead of the original TZ581 and 2N5172's. The CV summer can be the original LM301 Op Amp if you insist (you'll need to kludge in the bypass capacitor) or use a modern and more stable NE5534 or better still the OP177GP Op Amp.

The audio path Op Amps can be the original LM301's (if you kludge in the original bypass capacitors) or much improved modern and cleaner OPA134's (or NE5534's). I found the OPA134's to give a very nice sound, far better than 741's which I used in some tests.

The Tempco resistor can be omitted, and a standard metal film resistor used, if you are not concerned about the filter oscillation tracking properly. I have had 1K87 3500ppm Tempco resistors specially manufactured, and I recommend fitting one of them.

During testing of the prototype a 0.25V offset was found on the audio output. This has been resolved on production boards with the addition of a 220nF capacitor just before the output socket. The addition of this capacitor makes no sonic difference, but it does remove the annoying offset.

The REV03 board is the production board, with no errors or corrections.

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4 PCB

The PCB is double sided with solder mask and silkscreen on the upper surface. The component names are shown in the silk screen but not the component values. The size of the PCB is 80mmx100mm (actually it's 79mm x 100mm to enable panelizing).

The PCB is held to the front panel at 90 degrees by the use of two pot brackets manufactured by ECO. These brackets (and pots) are centred at 40mm apart. The FREQ and FINE pots hold the PCB to the front panel.

5 PCB Connections

The PCB has a number of connections designed for MTA 0.1" headers, so that the panel components can be connected to the PCB. I use headers and sockets to enable the board to be easily replaced, however you can solder wires straight to the PCB.

PCB Header Name	Pin #	What is it?	Where does it go?
INPUTS	Pin 1	Input Signal A	Wire to jack SIGNALA IN
	Pin 2	Input Signal B	Wire to jack SIGNALB IN
	Pin 3	Input Signal C	Wire to jack SIGNALC IN
SIGNALA	Pin 1	Signal A Pot	Wire to SIGNALA Pot Pin 1
	Pin 2	Signal A Pot	Wire to SIGNALA Pot Pin 2
	Pin 3	Signal A Pot	Wire to SIGNALA Pot Pin 3
SIGNALB	Pin 1	Signal B Pot	Wire to SIGNALB Pot Pin 1
	Pin 2	Signal B Pot	Wire to SIGNALB Pot Pin 2
	Pin 3	Signal B Pot	Wire to SIGNALB Pot Pin 3
SIGNALC	Pin 1	Signal C Pot	Wire to SIGNALC Pot Pin 1
	Pin 2	Signal C Pot	Wire to SIGNALC Pot Pin 2
	Pin 3	Signal C Pot	Wire to SIGNALC Pot Pin 3
RESO	Pin 1	Resonance Pot	Wire to RESONANCE Pot Pin 1
	Pin 2	Resonance Pot	Wire to RESONANCE Pot Pin 2
	Pin 3	Resonance Pot	Wire to RESONANCE Pot Pin 3
CV_INS	Pin 1	CV1 In	Wire to jack CV1 IN
	Pin 2	CV2 In	Wire to jack CV2 IN
	Pin 3	CV In	Wire to keyboard CV bus or optional CV select SWITCH
CV1	Pin 1	CV1 Pot	Wire to CV1 Pot Pin 1
	Pin 2	CV1 Pot	Wire to CV1 Pot Pin 2
	Pin 3	CV1 Pot	Wire to CV1 Pot Pin 3

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CV2	Pin 1	CV2 Pot	Wire to CV2 Pot Pin 1
	Pin 2	CV2 Pot	Wire to CV2 Pot Pin 2
	Pin 3	CV2 Pot	Wire to CV2 Pot Pin 3
OUTPUTS	Pin 1	Signal Output	Wire to jack OUT
	Pin 2	Signal Output for LED Meter	Wire to optional LED Meter Input
PAD	Pin 1	Panel Earth	Wire to jack socket earth bus

6 Pots

The PCB is designed to be used with Spectrol 248J conductive plastic pots; they are a reasonable price and very high quality. The PCB will work with either 3.18mm or 6.35mm spindle diameter models. The 6.35mm pot connections don't quite fit into the PCB holes so you wish to extend the pot connections with bare wire.

7 Power

The module should be powered from a well regulated +15V and -15V power supply, current consumption is around 25mA. The power connector is the standard two ground MOTM/Oakley 4-pin Molex connector. One ground is for the circuit, the other is for the panel (PAD).

8 Front Panel

The AM4023 is a standard AM format module which can be built into a number of panel formats. You can use your own format or choose from the following:

AM High Density

This panel format enables a higher density of controls on each panel, and panels are usually 90mm wide. All the pots have a small spindle diameter of 3.18mm which enables the control knobs to be located closer together. Both 19mm and 13mm control knobs can be used. The "look and feel" is similar to the ARP 2500.

Panels are 4U high and 90mm wide. Panels are fitted to horizontal 12mm angled aluminium strip using 4mm diameter machine screws in each corner of the panel. The strip is mounted into a standard 19" rack unit with small wooden end strips.

AM Low Density

This panel format has a lower density of controls on each panel, and panels sometimes have to be 135mm wide to accommodate all the controls. All the pots have a spindle diameter of 6.35mm which means 19mm control knobs can be used, such as those used in the Eμ Systems Modular. The "look and feel" is similar to the Eμ Systems Modular.

Panels are 4U high and 90mm or 135mm wide. Panels are fitted to horizontal 12mm angled aluminium strip using 4mm diameter machine

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screws in each corner of the panel. The strip is mounted into a standard 19" rack unit with small wooden end strips.

MOTM Panels
This established panel format has pot spacing very close in dimensions to the AM PCB's, MOTM is 41.275mm compared with 40mm of the AM format. This means you can design MOTM style front panels but with 40mm spacing and this won't look significantly different. Alternatively you maybe be able to mount the AM PCB on 41.275mm hole centres by slightly bend the pot brackets to fit.

9 Building the Module

This module is simple to build. The recommended build order is:

- Resistors
- Inductors
- IC Sockets
- Capacitors
- Trimmers
- Connectors
- Transistors
- Pot Brackets and Potentiometers

Check all the electrolytic capacitors and transistors are fitted the right way round. Before fitting the IC's its worth connecting up the module to a power supply and checking that the power rail voltages are as expected at each IC socket, then power down, and fit the IC's ensuring correct orientation.

Power up and try out the filter. Then proceed to trimming. Watch out for the speaker shredding resonance.

10 Trimming

This module has three trimmers which need to be adjusted for accurate operation of the filter.

FC_TRIM This trimmer adjusts the initial cut-off frequency of the filter. Set the FREQ and FINE pots to minimum and turn RESO (Q) up so that the filter begins to oscillate. Monitor the filter output with an oscilloscope or frequency counter and adjust FC_TRIM for a 62.5msec. period or 16Hz.

BALANCE This trimmer adjusts the two poles of the filters so that they have the same output levels. Set the FREQ and FINE pots to minimum and turn RESO (Q) up so that the filter begins to oscillate. Monitor the filter output and Pin 6 of IC4 with an oscilloscope. Adjust the FREQ and FINE pots to give a 1 kHz sine wave on the audio output of the filter. Adjust BALANCE to give the same level on both monitored outputs

Note: The official ARP trim procedure states pin 6 of IC4 should be set to half the filter output.

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V/OCT This trimmer adjusts the CV input response, so that the filter accurately tracks the keyboard and oscillators. Turn RESO (Q) so that the filter begins to oscillate. Patch the keyboard CV into the FM1 socket on the PCB. Press C4 on the keyboard and adjust the FREQ control so that turning V/OCT trimmer has minimal effect. Tune a reference oscillator so that it zero-beats with the note appearing at the Band Pass output. Be sure the reference oscillator is not controlled by the keyboard. Now, press C5 on the keyboard and trim V/OCT so the note from the filter zero-beats with the reference oscillator. Repeat as necessary.

11 Special Components

The AM4023 makes use of a small number of specialist components:

Tempco Resistor

The 1K87 3500ppm/°C Tempco can be obtained from Precision Resistors, they have UK and USA distribution. You need the PT146 resistor, and they may ask for a minimum order of 5 or 10 items.

http://www.precisionresistor.com/

A 1K8 1% resistor can be used if you aren't concerned about the filter tracking the keyboard when it is self-oscillating.

CA3080E

The CA3080E is now obsolete (as of 2005) but stocks still remain at many specialist electronic component suppliers.

Pot Brackets

ECO pot brackets can be obtained from Omeg in the UK.
http://www.omeg.co.uk/

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13 Component Listing

Capacitors			
C1, C3	100pF	2	Radial Ceramic
C2, C4	1000pF	2	Multi-layer Polyester or preferably 1% Polystyrene
C5, C10	220nF	1	Multi-layer Polyester
C6, C7	100nF	2	Axial or Radial Ceramic
C8, C9	22uF, 25V	2	Radial Electrolytic, 5mm spacing
Resistors			All 1/4W 1% metal resistors except where noted
R1	10K	1	
R2, R3, R7, R8	100	4	
R4, R10	61K9	2	
R5, R11, R26, R27, R29, R30, R31, R32, R33	100K	10	
R6	15K	1	
R9	81K	1	
R12	3M3	1	
R13	8K2	1	
R14	470	1	
R15	1K	1	
R16	150K	1	
R17, R24	56K	2	
R18, R22	2K2	2	
R19, R23	33K	2	
R20	475K	1	
R21	27K	1	
R25	196K	1	
R28	12K	1	
PTC1	1K87	1	+3500ppm/°C Tempco Resistor
Potentiometers			
RESO, FINE, FREQ, CV1, CV2	100K LIN	5	Spectrol 248 recommended
SIGNALA, SIGNALB, SIGNALC	100K LOG	3	Spectrol 248 recommended
Trimmers			
BALANCE, V/OCT	50K	2	Ceramic Multi-turn 3 pins in-line
FC_TRIM	100K	1	Ceramic Multi-turn 3 pins in-line
Semiconductors			
IC1, IC3	CA3080E	2	OTA
IC2	OP177GP	1	High Quality Op Amp. Can use NE5534 with no mods. Can use LM301 with mods.
IC4, IC5	OPA134	2	High Quality Op Amp. Can use NE5534 with no mods.

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			Can use LM301 with mods.
D1, D2, D3, D4, D5	1N4148	5	Diode
T1, T6	2N3906	2	Transistor
T2, T3, T4, T5	2N3904	4	Transistor
T7, T8	2N5459	2	FET
Other Passives			
L1, L2		2	Inductor
Hardware			
CV_INS, OUTPUT		2	MTA 0.1” 2-pin header
INPUTS		1	MTA 0.1” 3-pin header
POWER		1	MTA 0.156” 4-pin header
		2	ECO Pot Brackets

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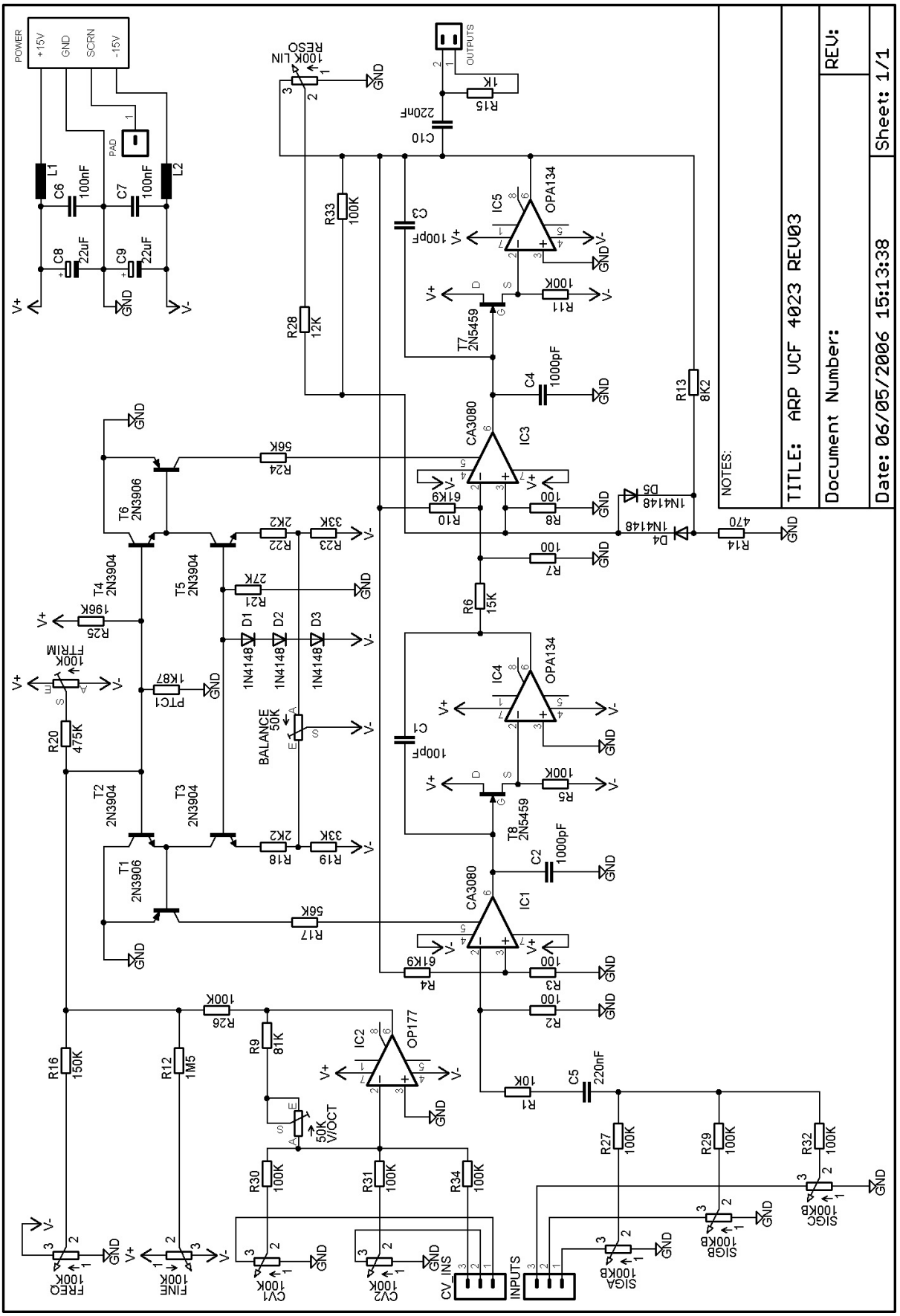

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