Analog Computer : Anabella

The basic goal is to build a machine comparable to the basic analog computers used (occasionally) in education, with enough functionality to be able to model some 'standard' systems:

- damped mass on spring
- bouncing ball in a box
- Lorenz Attractor
- 3-cell Cellular Neural Network

Metering with be done externally. (maybe a later unit containing meter + speaker + Arduino-based 'scope). It should be worthwhile allowing for some level of external control (ie. for resetting the integrators) to allow an Arduino or whatever to interface, making a hybrid computer.

My plan is to use an A4 plate as the front panel, which gives a nice physical limit on what is possible. This form-factor I believe should also work as a good alternative to finer-grained modular setups such as those based on Euroracks. Connectors will be 2mm banana plugs/sockets.

Standard analog chips will be used inside (probably mostly TL072 op amps), powered at +/- 15v, using +/- 10v as the value range.

I'm not aiming for high precision, but may have a bit of trimming for things like offset on the pots. etc. Using typical inexpensive components such as 1% metal film resistors, that 1% seems a reasonable target (capacitor tolerance will be the weakest link, though hopefully hand-selecting individual components will minimise error here).

Proposed Functionality

Control Unit

- Power switch & LED
- Set initial conditions - NB. Allow external reset
- Run
- …

Modules

Component	Quantity	Control	Inputs	Outputs	Tot. I+O
Voltage Ref.	4	-	-	4	4
Coefficients	6	pot	1	1	12
Free pots	2	pot	3	-	6
Summers	4	-	4	2	24
Inverters	4	-	1	2	12
Integrators	4	Switch	3	2	24
Multipliers	2	-	3	2	10
Log	1	-	1	1	2
Exp	1	-	1	1	2

(96 connectors there…maybe 12x8 = 96 available)

TBD

- comparator(s)
- rectifiers(s)
- function generators(s) (transfer function)
- function generator (sig. gen.)
- clock

Voltage Reference

2 x 10v
2 x 1v

Coefficients

6 x potentiometers with one terminal grounded, feeding unity gain buffers

Free pots

2 x pots, all terminals exposed

Summers

4 x op amps in **inverting** configuration

- 3 x1 inputs
- 1 x10 input
- 2 outputs

Design Considerations & Implementation

The first question here was whether to use inverting or non-inverting configurations. There are two problems with the non-inverting setup, first is that the gain calculation is a little more complicated (not really an issue), second there is interaction between different inputs. The usual inverting setup has the input resistors connected to the (-) op amp input, which is forced by the feedback to stick at virtual ground, thus removing interaction. The drawbacks of using the usual inverting setup are that the input impedance will be much lower, and that - well, they are inverting. But the input impedance will typically be much greater than the output impedance from which the units are fed, so this shouldn't be an problem in practice. The overhead of providing a -1 inverter per summer is low and alleviates the other problem

Many historic analog computers expose pretty much the whole of the op amp. In particular, those using an inverting configuration allow access to the virtual ground point allowing arbitrary feedback components. Here, to keep things simple, this won't be the case. Instead, the straightforward summer model will be used.

Checking the TL07x datasheet and breadboarding, the simple inverting configuration appears to be perfectly adequate given the overall accuracy goal of around 1%. A feedback resistor of 100k, input resistors of 3 x 100k & 1 x 10k seems fine.

Inverters

4 x unity gain op amp inverters (ie. -1), 1 input, 1 output

Like the summers, a 100k input & 100k feedback resistor should be ok.

Integrators

4 x op amps in **inverting** configuration, with switched capacitor for time constant, with analog switches handling initial conditions/run

Multipliers

2 x AD633