Building a Modular Synthesizer – Where To Start

I want to build a modular synthesizer but don't know where to start!

A short question with, unfortunately, a VERY long answer (or set of answers).

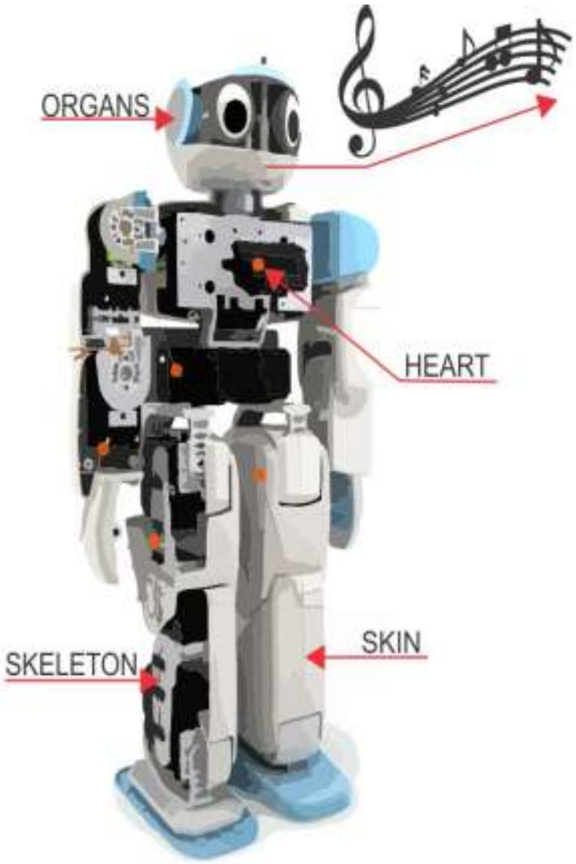
For the purposes of this article we will assume that you do not want to 'get your hands dirty' and get involved with woodworking, metalworking or any other work involving these sort of manual skills. The assumption, therefore, is that all items used must already exist in one shape or form.

References and examples of 3rd-party solutions will be used throughout this article. The use of these is purely to highlight a point and is not intended to be a comment on the suitability or otherwise of those items.

We will, obviously, discuss products from the ELBY Designs product range but variations of many of these parts are also available from a number of 3rd-party suppliers and so what is discussed here should be relevant to those products as well.

A synthesizer system comprises the following major elements:-

1) *skin* - external housing - used to provide overall protection for all the other elements listed below. Standard offerings comprise wall-mounted, free-standing, desktop and semi-portable units.
2) *skeleton* - sub-rack - provides the major support structure for all the modules to be installed.
3) *heart and arteries* - power supply (heart) and distribution system (arteries) - allow the system to run and provide the means to get power to each of the installed parts.
4) *organs* - modules - the bits you play with and that do the actual work of making sound.



ELBY Designs - Laurie Biddulph
9 Follan Close, Kariong, NSW 2250, Australia
elby-designs@bigpond.com http://www.elby-designs.com

The SKIN

You will need to protect your investment from dirt and damage, and you will probably want it to look 'right' in your environment. This is possibly one area where off-the-shelf might not be the ultimate answer as doing-it-yourself will allow you to get the right size, shape and colour that YOU want.

The most common materials used here are wood and metal. Metal is a better engineering solution as it can provide important screening for the electronics in your synthesizer protecting it from external contaminants such as radio waves, electricity and magnetics. Wood can either be used as a cheaper housing solution or to provide a high-quality visual finish for your system.

Other materials including perspex and other plastics are often used but these have potential problems from electrostatics if proper measures are not taken to eliminate those problems.

The case can be either a separate entity from the skeleton or actually integrate the skeleton parts within the construction of its fabric.

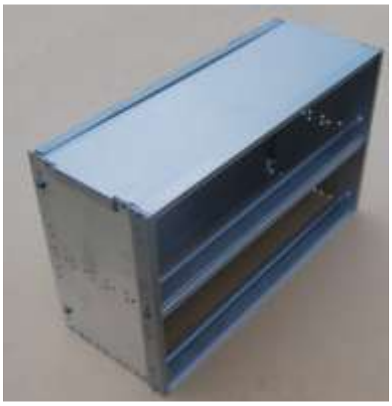
The SKELETON

This is the frame in which all your modules are mounted. As a minimum it comprises a pair of rails which span the width of the frame and these include a fixing strip that allows installed modules to be held firmly in place.

The common term used for this frame is sub-rack, although we refer to them as Tower Racks. The standard (and original) sub-rack comprises a set of rails supported at each end by a side panel and joined at the rear by a back panel. Optionally a top and bottom cover can be added to enclose the assembly.

These are generally made from aluminium providing a light but sturdy assembly that can also provide a good degree of electrical insulation from pollutants such as electro- and magnetic radiation.

The side panels dictate the vertical spacing between the rails and in the EuroSynthesizer world this is fixed at 3U which is equivalent to 5.25" or 133mm. Multiple 3U sub-racks can be stacked together to form taller systems with 6U and 9U being the more common heights. Systems above 18U tend to be less common due to the need for extended patch leads to reach from modules in the top row and modules in the bottom row.



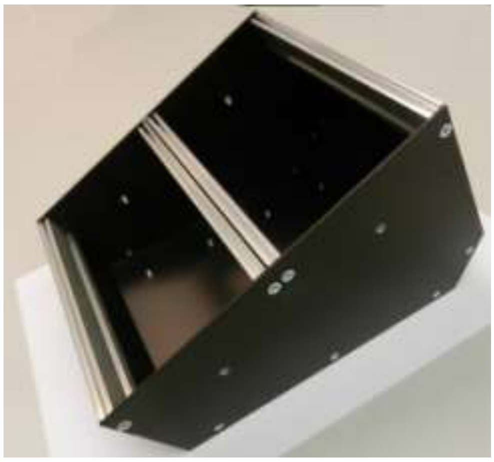
The back panel provides an ideal platform for mounting power supplies and busboards. In the standard sub-rack the back panel is set back approximately 160mm allowing ample room for a variety of module depths and allowing for good cable routing between the modules and busboards. This depth also provides a more controllable thermal environment helping to reduce problems associated with thermal gradients in a system and moving air currents.

As can be seen in the picture at right of a sub-rack complete with a top cover, it is quite possible to use these sub-racks without an external skin. If you don't mind the industrial look then this can be a useful option for budget conscious systems or for those wishing to take their time in investing in a high-quality case and need to get up and running straight away.

Simpler frames that comprise just the front rails and narrow side panels are now becoming a favourite with DIYers. These sub-frames, we refer to them as Lite Racks, allow the user to determine their own case depth and profile and permit the construction of really shallow cases or skiffs.

As the Lite Rack does not have any back panel and minimal depth side panels, the user has to come up with a solution for mounting busboards and power supplies and may need to consider screening options to prevent possible noise problems.

Another solution is an integrated case where the case and frame are all integrated. We refer to these as our Studio System and they comprise a pair of profiled side plates which support the rails and a skin that wraps around to form the back, top and bottom of the enclosure.



The HEART

The power supply forms the heart of the system and works in conjunction with the arteries to get power to each of your modules.

There are 3 main approaches to providing power for your system:-

1) external dual-rail supply
2) internal supply
3) distributed supply

Each of these methods has its advantages and disadvantages and these need to be weighed up when deciding on the approach you adopt for your system.

1) The external supply is normally a single power unit that perform the following 4 steps:-

a) connects to the local mains supply,
b) converts the high voltage mains AC in to a low voltage DC
c) regulates that DC in to a stable dual-rail supply
d) provides one or more outlets for connecting to your system

The main advantages of this approach are that the associated problems of mains voltages, weight, size and heat generation are kept outside and away from your system.

Mains voltages can present a health risk and can also introduce hum in to your system and so it is desirable to keep these as far away from the system as possible.

All power supplies generate heat and again it is desirable to keep this heat away from your system as it can introduce instability in some modules especially if it is not properly managed inside your system.

A single supply capable of providing all of your systems power needs could be quite large, especially if you opt for a full linear design that involves transformers and heatsinks, so sometimes, in really large systems you may need to resort to two or more supplies to meet your systems demands.

2) The internal supply is mounted inside your system. Depending on the physical size of your system, the loading of the modules and the capabilities of the supply you may have more than one internal supply fitted.

This approach separates steps (a) & (b) from steps (c) & (d) leaving the first section as an external part, usually in the form of an inline supply recognisable as the laptop supplies used for powering laptop computers.

3) The distributed supply is the nearest to the ideal solution and provides a small power supply for each and every module in your system.

By providing each module with its own dedicated supply, many of the issues with the other approaches can be greatly minimised if not eliminated.

This approach is also the most flexible of the 3 described as expanding your system, and so increasing your load requirements, is addressed by simply adding more distributed supplies. The user will still need to be aware of the rating of the external power supply but these are generally a much lower cost item than any equivalently sized external supply as required in approach (1).

A fourth approach offers an even better solution but does require a different approach to the main power source and distribution. In this approach, each module has its own onboard +/-12V regulator. The distribution system then comprises a simpler +/-15VDC supply.

SMPS or LINEAR?

One topic that nearly always arises when discussing power solutions is the use of SMPS (switched-mode power supplies) or LINEAR supplies.

The first point to mention is that any noise that appears on the power supply rails can inadvertently affect the operation of some modules connected to those rails and in some cases can exhibit itself as noise in the audio path (hiss, static etc).

A good quality supply and proper power distribution are key elements to controlling these problems but the choice of supply technology can also be a factor.

Modern LINEAR supplies are generally recognised as having extremely low-noise and high-stability outputs. These characteristics are required in the audio industry where these sort of problems can not be accepted and so the general term audio-grade is often applied to power supplies that generate power rails of this kind of level.

The biggest downside of LINEAR supplies is that they inherently require heavy transformers and bulky heatsinks and so LINEAR supplies for large systems also tend to be large and heavy.

Recent improvements in SMPS design now allows them to be used as an alternative to the larger bulky LINEAR supplies but, due to the technologies used, they generally tend to have much higher noise levels and tend to have less stable outputs than their LINEAR counterparts. In general, it would be safe to say that SMPS solutions are not generally considered as audio-grade.

As a result, many users frown upon the use of SMPS as the power solution for their systems. You will hear arguments from users of SMPS supplies that they do not have any of these issues and that it is paranoia that turns some people away from them. On the other hand you will probably find as many people who do have issues when using SMPS supplies although these will tend to be more supressed in the interests of the manufacturers concerned.

Various legislative rulings applicable in many countries around is forcing the market more and more towards SMPS due to their higher efficiency and better carbon-friendliness. It is also a requirement on most power supply solutions that they be compliant with various electrical and safety standards (CE, UL, FCC etc) and the costs associated with these approvals can be quite prohibitive and out of the reach of the smaller solution supplier. The solution adopted by most people in this situation is to use an existing off-the-shelf mains supply which is already compliant with the relevant approvals and to use this to power a small sub-power supply. Although this does not alleviate the responsibilities of these suppliers to provide compliant power solutions, it does reduce the cost burden substantially.

With the growing popularity of the dual-system there are a growing number of linear regulators designed with the requirements of being used as post-SMPS regulators and consequently offer a much higher degree of filtering of the high frequencies. Power solutions built using the regulators can be considered as approaching, if not achieving, auto-grade performance.

The Arteries

The arteries provide the mechanism for getting the power from the power supply to your individual modules. The distribution system has 2 major tasks:-

1) distribute the power evenly, cleanly and reliable around your whole system, and
2) provide adequate 'access points' for all your modules

Compromises here could result in your system being unable to maintain a stable power supply.

As part of achieving the requirements of (1), distribution systems should make extensive use of VERY low-impedance busbars and connectors. The use of mechanisms such as flying busboards should be frowned as they can never approach either of these aspects. Some manufacturers replace the common module power cables with low-impedance cable and connectors. However, this approach does mean diversifying from the 'standard EuroRack' methods and so is more viable for dedicated custom designs.

The big issue all manufacturers have is the fact that the original EuroRack specification for power distribution is flawed and not ideal, but at the same time it is the most prominent and supported method adopted by virtually all EuroRack manufacturers. To adopt a system that is 'technically correct' would also mean adopting a system that is inherently incompatible with the major market sector.

The EuroSynth specification lays out a solution that remains compatible with the EuroRack market yet aims to offer an improved performance.

ELBY Designs - Laurie Biddulph
9 Follan Close, Kariong, NSW 2250, Australia
elby-designs@bigpond.com http://www.elby-designs.com

The ORGANS

This is where the fun really starts. Modules are the individual building blocks of your modular synthesizer. By adding modules you will be able to create a synthesizer that sounds and operates how you choose. Modules come in a large variety of sizes and functionality from a myriad of different manufactures.

VCO (Voltage Controlled Oscillator)

This module is essentially what produces sound. Voltage inputs are commonly CV-Pitch, Sync (for having multiple VCO start in phase with each other), FM input , and PWM input (Pulse width Modulation input) Different oscillators will have different characteristics. Some modules may have an odd shape to the triangle wave or maybe have interesting pulse width characteristics. Many of these modules vary in size but that does not mean a smaller module has a weaker sound. Looks can be deceiving sometimes.

How well VCO's track refers to how well they stay in tune as you play notes up the keyboard. Some VCOs might have an unruly character and only track a few octaves while others may be rock solid across 6+ octaves. Keep this in mind when selecting a VCO.

Outputs are commonly regular waveform outputs such as square, saw, triangle. The outputs of these oscillators are always on so if you plugged the output directly to your mixer you would hear the oscillator and it would not stop.

This is why we use envelopes and amplifiers

VCF (Voltage Controlled Filter)

The filter allows us to sculpt the sound of the VCO pretty straight forward as on most synths. Filters are commonly low pass (LP), high pass (HP), notch, and band pass (BP). Some inputs can be CV input for opening and closing filter, CV input for resonance, Pitch input for resonance key tracking, and of course audio input.

Filters can also be considered "low pass gates" and can involve features such as vactrol inputs which take a simple square or sharp on off signal and can round it out for a more pleasing sound.

Filters can also be used to shape control voltage as well. This can cause simple gates to act as more interesting rounded signals or pitch to have a slew.

VCA (Voltage Controlled Amplifier)

The VCA is an important part of a modular system. this is what decides how loud a particular sound is and can be controlled from other sources. A common usage would be to send a VCO into the VCA and have it controlled by a gate on off or envelope opening and closing. Also it can have more alternative sources such as LFO's controlling a VCA to get tremolo or swelling effects. VCA's can also be used to attenuate levels to match your needs.

ADSR or EG (Envelope Generators)

Envelopes are a common building block and are used to decide how fast or slow a gate is used. When you press a key a gate is sent as an on (positive) signal, and when the key is released the gate is turned off (the resulting output when viewed on a scope would be a positive square wave). An envelope can allow that immediate on off into a gradual on or gradual off. This is used to make more musical and pleasing on off note signals Attack Decay Sustain and Release are the common parameters.

Some envelopes also have looping features and can allow them to act as LFO modules.

LFO (Low Frequency Oscillator)

Low frequency oscillator is used as a modulation source. Think of them as a slow moving VCO that can be used to raise and lower other modules parameters. LFO common uses include being routed to a filter CV input to open and close a filter or to a VCA to create warbling or pulsing sounds. Wave shapes vary from LFO to LFO and can add variety to your sound. Many VCO can act as an LFO as well.

Mixer

A mixer is just what it sounds like. A way to mix multiple signals into a single (and sometimes multiple) outputs. Use this to connect all of your VCO modules before sending into a filter. Mixers can also be used for control voltages to interesting effect as well. Mixers can come in a variety of input and output configurations… not all mixers are the same!

Multiples

Multiples and buffered multiples are used to send single signals off to different sources. Think of it as a splitter. Buffered multiples prevent voltage drop from splitting off to many destinations. Multiples can be easily built DIY projects or you can get them on the cheap. Buffered multiples tend to cost a tad more but are great for sending pitch out to many sources while keeping tune.

Sample and Hold

Sample and Hold is a module that takes a fluid CV or audio source and turns it into a stepped output. The amount of steps is decided by a clock or pulse input. This can create some interesting effects such as bit reduction sounds, or jagged pulses.

Effects modules

Just like a guitar pedal board, EuroRacks can have many different effects. Effects can range from the standard spring reverbs and delays on and off, to control voltage effects such as stutters quantizers and retriggers. There are also CV effects such as gate delays and trigger offsets etc that will change the CV going into and out of a module.

Sequencers

One of the really interesting things about modulars is that you don't have to use a traditional keyboard to play them. EuroRack has MANY sequencers and alternative input sources. Ranging from random voltage generating sequencers to deliberate step sequencers and everything in between. You might be surprised at some of the rhythms and melodies that can spring from these sorts of modules.

COMBINED MODULES

Many Modules have combined features to save space or just plain be more value per dollar and interesting.