Son Of GX!

Rebuilding the Yamaha Electone E70 into a fully programmable monster synth

Fig. 1: Such a powerful instrument could be yours for easy money. But are you brave enough!

1 Introduction

Want to own your own analog megasynth without paying a fortune?
It can be done. I did it. And so can you. If you´re brave enough.
Ever since I bought myself an old Yamaha Electone E70 organ, customized the hell out of it and posted proof of the results on YouTube people have been asking me to tell them how I did it.
No problem! It doesn´t make sense to keep my knowledge to myself for commercial reasons. And why shouldn´t the wold be a nicer better place, filled to the brim (!) with customized Yamaha´s, blaring out nice music.
So read on and be amazed! Or better still: Be afraid. Be very afraid!

But first:

In principle those who are only interested in the actual customizing information could skip the first 3 paragraphs. Paragraph 1 tells about the history if the idea. Paragraph 2 contains some background information. Paragraph 3 describes the principles behind the customization process and what one is getting him/-herself into. Paragraph 4 describes the actual customization process. Paragraph 5 philosophizes a bit about the result.
I would recommend that besides paragraph 4 you at least also read paragraph 3 because it contains some basic understanding of what you are getting into.

And another thing:

The disclaimer part. It must be clear that those who attempt to do what I did do so on their own risk. As you can read below such a project hovers somewhere between rather do-able and extremely complex. You could get there in the end but you can also get electrocuted, damage or set fire to your instrument, your house or whatever.

If anything goes wrong you can´t complain to Yamaha (They hardly remember they ever built this thing), but I also will not accept any blame.
You yourself should be aware of what lies within your powers and if you are prepared to do what it takes.
So if you have got two left hands, don´t even think about it.
Feel brave? Do it.
But don´t be stupid. It all starts with discipline, Grasshopper. A lot of self discipline.

And yet another thing:

Although I put the information in this article into the public domain I would like you to respect the work I put into its. In so far all copyrights still apply. So If you want to use the actual content of this article for other purposes then your own customization project better contact me first.

And just before you finally loose your confidence: Here is a reminder of what this is all about and what might await you at the end of your quest:

Specs (after rebuild)

- 2 Fully programmable polysynths
- 1 Fully programmable pedal bass synth
- Classic Yamaha CS type analog synth architecture
- extra fully programmable organ layer per section (upper, lower, pedals)
- 2 Detunable oscillators per sound source (synth and organ)
- Section layering (upper + lower keyboard and/or lower keyboard + pedals)
- Expressive foot controller (overall volume and upper manual filter cutoff)
- Versatile arpeggiator (lower manual section)
- Analog drum rhythm patterns
- Preset auto accompaniment patterns (based on drum presets)
- Integrated arpeggiator / auto-pattern / drum synchronization
- Stereo outputs for extremely wide sound field
- Individual output per sound source
- Mechanical rotary speaker
- Extremely ergonomic layout
- More then 300 individual hardware controllers

In short: It´s the best of both worlds in analog synth and organ technology!

2. History

2.1 The road to a crazy idea

A few years ago I stumbled across some very information on the internet suggesting that Yamaha´s analog synth technology of the late seventies, which brought forth such excellent instruments as the GX1 and the CS-range of synthesizers, had a directer connection to their Electone range of organs then I had ever suspected.
I must admit that in the thirty odd years I have worked with synthesizers I always looked down on organs. They seemed the easy way out. Presets sounds, preset patterns, preset rhythms. Surely only ``real synthesizers`` where the proper tool for true creativity. I even looked down upon preset synthesizers. Only blundering fools would want to use these crutches.
But as always things tend to be more complex in real life. Little did I know that some of these preset instruments where actually much more playable ans expressive from a purely musical standpoint then many fully programmable synthesizers.
He or she who has ever tasted the delight of playing with the aftertouch sensitivity of ARP´s ProSoloist or a Roland SH 2000 will know what I mean. It might be a preset synth, but boy, can it sing.
Another example is how the expressiveness of a Yamaha CS80 can be explored without ever touching the programming section. A CS80 without voice channel programming section would still have been one of the great synthesizers of all time.
But why did this simple insight turn out to be so important to me?

Well then I must go back even further. After I acquired my own CS80 more then 10 years ago, oh glorious day, a curious questions kept popping up in my mind: What ever could could better this instrument as far as analog synthesizers go? Nothing for sure! I could fill my whole house with ever more instruments without ever getting the kick again I got when I first laid hand on my CS80. Furthermore the very idea sounded a bit too decadent to me! So had I all too suddenly ended my quest?
Furthermore the CS80 is a temperamental beast. Mine once developed a minor fault and I searched for a technician who was able and willing to repair it for more then a year. In the end I gave up hope and decided to get in there myself. And lo and behold: Although I do not know that much about electronics I was able to find and correct the defect.
For both reasons I decided it was time to learn more about analog synthesizer technology. It was time to get my hands dirty.
But I didn´t want to experiment on the few fine instruments I had already acquired, so the next idea then seemed quite logical: If there is nothing better out there why not get creative and start building or customizing my own stuff. The results might very probably never get anywhere near to the level of a CS80 but it would be nice to exploit one´s own idea´s about the ``perfect`` instrument while learning more about the technology.

2.2 First forays

Time to do some more research. So what did the internet further tell me? First of all that if there ever was something that possibly topped the CS80 it was Yamaha´s GX1, Yamaha´s supersynth of ELP, Led Zeppelin, Stevie Wonder and Abba fame. Wow! Talking about unobtainable!
But it soon turned out Yamaha actually included their first forays into analog synthesizer technology in their cheaper Electone organs.
Now secondhand Yamaha Electone organs are cheap and plentiful. Cheap meaning that it would not cost an arm and a leg to buy one and then damage it beyond repair. Plentiful means that it should be easy to track an interesting example down.
The Yamaha CSY/1 organ, for instance, contains a fully fledged SY/1 synthesizer. They are actually filled with GX/1 parts and cost next to nothing while standalone SY1 and 2´s already cost s few hundred Euro´s.
So I bought a CSY/1 (Eu 50 + transportation expenses) and got cracking.
I was able to make the aftertouch sensitive preset synth fully programmable and rplaced the lower manual with the keyboard and electronics of a Korg Poly 800 organ. The result I called the Polycheesy GX-800 as a pun to indicate it inspiration.
But that´s a tale in it´s own and should therefore be told elsewhere. Sufficient to say that I had learned you could turn an early preset analog synth into a fully programmable one without being a total electronics buff.

2.3 The stage is set

In the mean time I had tracked down information that Yamaha´s P.A.S.S. Organs might actually contain a lot of CS-technology. Especially the E70 was mentioned time and time again and one Flametopfred on YouTube actually proved how good even a fully original E70 sounds. Especially Flametopfred´s ``Fool´s Gold Overture`` got me hooked on the idea (thanks again Fred!).
On internet forum´s the idea was discussed regularly to turn an E70 into a programmable synthesizer. Imagine that: Three programmable synthesizers in one instrument. Analog heaven near to a GX1 would be the prize for he who succeeded.
Could it be done at all? Could I actually do it myself? Or would this be one bridge too far?
Well I could at least try to get hold of a E70. For Eu 300 plus expenses I was able to obtain a reasonable example. Furthermore I traced down the technical documentation for Eu 35 plus postage. Not cheap but it would be nonsense to try anything without the schematics.
In the meantime I found out that somebody had actually done something comparable already. An E75 (the E70 with added string and choral presets) had already be fitted with a programmable Upper Orchestra Section.
So I would´t be the first to get there after all. Gone where my dreams of ultimate glory!
But on the other hand this proved that it could indeed be done. If one section could be converted then all three of them could too!
Oh, brave new world!
The stage was set indeed.

3. Background information

So you feel lucky, punk?! You think you can do it to? Better read this paragraph first.

3.1 Why it is dead easy?

It´s so easy! Actually the biggest part of the whole operation is based on one single principle, namely to exchange fixed resistors with variable resistors, also named pots. So it´s just a matter of doing a bit of soldering, now is it?
Indeed. In principle that is all there is to it. Modifying an old and almost totally analog beast actually has it´s advantages. Nowadays synthesizers almost exclusively are reigned by software. That´s very nice and efficient as long as nothing breaks down or you do not want to change anything, but in the good old days of the late seventies almost everything was still taken care of with analog components.
So if you can read a map e.g. an electronic circuit diagram a bit and can handle a soldering iron without mutilating yourself for the rest of your life you are ALMOST in business.

3.2 A bit of theory first

One of the most common components in electronic circuitry is the resistor.
Now I am not a qualified electronics engineer, so forgive me if I make some small mistakes in the following lines, but this is how I understand it.
In an analog circuit the different component influence each other. Even if the resistance in one connection within a circuit differs the resulting analog signal coming out of it at the end will change.
In principle you could change the resistance in such individual connections by using connecting cables of differing cross sections and materials. You can compare this to water running through pipe systems. Differing cross sections of pipe will (at a constant water pressure) lead to differing amounts of flow. But that wouldn´t be very practical: In the case of an electronic circuit this approach would necessitate the use of an almost endless number of different cables cross sections.
That´s why the resistor was invented. You can compare a resistor to a little gate in the connecting line. In a thick water pipe you can include a little disk with a small hole in it. By using disks with varying hole diameters you can regulate the flow independent of the actual pipe diameter. In a comparable way an electronic resistor squeezes back the electron flow through an actually oversized cable.
Let´s go back to the comparison with water in a pipe one more time. Now what do you do if you want to regulate the flow of water in a certain pipe. Yep, you build in a tap in stead of the fixed disk. When you open up the tap a little bit a small amount of water flows through. If you open it up more water flows through.
Now what do we call an electronic tap? We call it a variable resistor.
How does that look in real life? Like a pot or a fader.

3.3 Getting there

Blah, blah, blah. Does all that talk about plumbing mean anything to you?
It should!
In every preset synthesizer (of the late seventies analog kind) all the settings are determined by fixed resistors.
These are typically placed in a so called matrix (no not the film, stupid).
You could look at a matrix as sort of knitting work of voltage lines.
What do all these voltage lines do? They instruct different parts of the overall circuit that determine certain functions how to behave(for instance the filters).
So what do you do when you need different settings for different presets? You divide the main voltage line in just as many parallel lines as there are presets. And at the start of every line you place a switch. With that switch you choose which line is opened towards the rest of the circuit. When you also make sure that only one switch can be opened at a time you are in business. By pressing one of the preset switches you ``gate`` the electric flow to the part of the system that controls the preset settings.
But a synthesizer voice needs a lot of settings per preset sound. That´s why you need a matrix. By splitting the voltage line after the selector switch and placing differing resistors in each individual line, controlling every available synthesis parameter, you ``pre set`` the whole sound.

3.4 Programmability

Stay with me. We are almost there.
Now what do you do if you want to have a programmable synthesizer?
Let´s get back to the pipework example one more time. You simply yank all the fixed flow plates out of the pipes and substitute them for taps.
In electronic terms: On one of the presets you exchange all the fixed resistors with variable resistors and presto: Your preset synthesizer has gained a programmable section.
Now that isn´t rocket science,is it?
I decided to do this to the Funny II preset in the E70´s preset Orchestra sounds. It´s not a bad sound at all but not as versatile as others and its switch conveniently sits at the end of every preset row. But one could just as well decide to use one of the other switches.
To avoid confusion I will however stick to my choice for Funny II further on in the text.
Just to be totally clear: If you have finished the job that single switch will take you into full programming mode. All the other factory presets will stay available a such. Now, isn´t that neat!

3.4 So why then is it still hard as hell!

Yep, that´s all there is to it. And that´s why you do not need to be an electronics engineer to do it. The Yamaha designers took care of all the difficult stuff and you only have to expand on their design in a very straightforward way.
Simple!
But let´s get real here. You need to build in pots for every synthesis function. The preset matrices in the E70 Orchestra Sections control for 13 parameters. So if you want to set all the parameters for every Orchestra Section, of which there are 3, you need to install 3 x 13 pots = 39 pots in total!. Gulp!
Oh, I forgot something. You probably also want to select the oscillator waveforms of which there are 3. For all the 3 sections that means another 3 x 3 = 9 switches, including the necessary wiring. And you obviously want individual outputs to process the individual sound sources or combinations thereof. Add a minimum of 11 jack outputs for that.
Furthermore you must build a controller box, design panel layouts, mount the pots, switches and output´s into the box and solder hundreds of connections to make everything work.
And it´s guaranteed that when everything seems to be ready and you start the damn thing up for the first time that some connections will be faulty, however precise you did your work, and it will take you days or weeks to get rid of these gremlins.
In short: You must be totally crazy to even contemplate such a venture! Believe me. I know. I did it. And yes, if you really insist: I indeed am crazy.

So before you start yanking wires out of your beloved E70 you first have to answer the following questions:

1. Are you also crazy enough to take this upon your shoulders?
2. Do you dare to open up such a complicated instrument and start messing around in it?
3. Are you disciplined and precise enough to not mix things up? You don't want to damage something essential, now do you?
4. And should that happen: Can you live with yourself it if you mess things up and are left with a defective piece of junk in stead of one of the nicest vintage organs available?
5. Do you not only have the intention to start to start this job but also to determination to finish it?
6. Do you at all have the time for this?
7. Are you handy enough to build the necessary hardware?

Only if you can answer all the above questions with a resounding yes you should start the journey. The only alternative would be that you are rich or lucky enough to have somebody else so it. But who in his right mind will do such a thing for you while risking to get the blame for an eventual failure.
Anyway, there is no sound economic basis for doing this job. E-series Electones are not considered to be worth much.
Furthermore collectors hate customization jobs so rebuilding it will never add much to the value, even if the E70 still becomes a collectors item in the end.
But then again: I only dared to treat my own E70 so disgracefully because there was not much financial loss involved if a big mushroom cloud would appear above it (providing I could still save the house around it).
So the only reason to do it is that you crave for the monstersynth that is hidden in there and the music that can be coaxed from it enough to leave behind every other consideration.
So don´t say I didn´t warn you (again).

4. The actual customizing guide

Fig. 2: My solution for the controller box, based on the original music stand.

4.1 ``Designing`` the hardware

You want me to hand you an exact design? You want me to send you the precise panel layout? Well that´s where the buck stops. That would be too easy, now wouldn´t it?
I actually want you to get creative yourself. We are not talking about some production instrument here. Many roads lead to Rome and this is your chance to really put your own signature on the result.
What I will do however is describe what I did. And you can then decide on how close you stay to that approach.
First of all you need to build a controller case for all the knobs, sliders and switches that you are going to use.
Off course you can start totally from scratch but here is what I did:
The original E70 music stand has 5 sections of which the 3 central one´s are rectangular. This almost seemed to contain an intentional symbolism: I wanted to make all 3 synth sections fully programmable and the 3 central panels where big enough to hold all the pots per section.
Another advantage was was that I would start with an element that already fits perfectly into the existing design.
Therefore I decided to use the music stand as the front of my controller box.

13 Synth functions are combined in the preset matrix:

4 Filter controls
- Low pass filter frequency
- Low resonance
- High pass filter frequency
- High pass resonance

5 stage Filter Envelope Generator
- Initial Level
- Attack level
- Attack
- Decay
- Release

4 stage Voltage Controlled Amplifier Envelope Generator
- Attack
- Decay
- Release
- Sustain

Note: Yamaha uses terms like first and second decay in the original documentation. I decided to use the names given to the same parameters on the CS80 because they are nearer to the standard terminology most manufacturers use.

I adhered to the subdivision mentioned above in using gray, green and red knobs for the mentioned subgroups. I did however not adhere to Yamaha´s original color coding but let a more visually pleasing layout

prevail. Purists could however use to the original Yamaha coding from the CS synthesizers.
Furthermore you could go for sliders in stead of pots (very CS indeed!).
After deciding on the central panel layouts, what more was there to do?
I decided to integrate the waveform selectors in to the far left, asymmetric panel. Off course more oscillator functions are available (like octave selection and detune) but these are already accessible elsewhere on the original E70. So there was no reason to include them again here.
I only wish I could have integrated noise generators. But then I would have to integrate some new electronic circuits into the design and I know very little about that. Maybe I´ll get around to it later.
I dedicated the far right, asymmetric panel to the individual outputs. I decided to use simple jack outs. It adds a semi-modular charm to the layout. One could however also choose to mount these outputs at the back of the controller box or the actual instrument.
After I had determined the layout I built the controller box from wood. It only has to contain the switches, spots and wiring but I decided to make it quite roomy anyway. Better to have too much room then too little. You never know what the future holds.
Next came the decision to use connectors between the box and the instrument or not. This more then doubles the amount of stripping, soldering etc. but I still decided to do it. After all: If you need to transport the instrument it can be quite awkward if a box is dangling from it. Furthermore it makes it possible to use the same box on another modified E70 later without having to start from scratch. Again: You never know what the future might bring.
On the other hand the chance of bad connections is much higher with extra connectors. So you might still decide against it yourself.

4.2 Choosing the hardware

The next step is to acquire all the electronic components you need.

4.2.1 The waveform switches

More then one waveform can be activated at once. So you do not need self-canceling switches. Simple singular on and off switches will suffice and you can choose your own favorite design. But remember 3 switches x 3 Orchestra sections = 9 switches in all.

4.2.2 The pots:

I simply started with linear 100K pots. Later on, after checking out the functionality of the whole system, I eventually decided on the following pots.

4 Filter controls		
	Low pass filter frequency	10 kOhm
	Low resonance	47 kOhm
	High pass filter frequency	10 kOhm
	High resonance	47 kOhm
5 stage Filter Envelope Generator		
	Initial Level	47 kOhm
	Attack level	47 kOhm
	Attack	100 kOhm
	Decay	47 kOhm
	Release	100 kOhm
4 stage Voltage Controlled Amplifier Envelope Generator		
	Attack	100 kOhm
	Decay	47 kOhm
	Release	47 kOhm
	Sustain	100 kOhm

Remarks:

- All the above pots are of the linear type to avoid too sudden changes at the sweet spots.
- Again: Remember you need 3 x 13 pots = 39 in all!
- The Initial Level and Attack Level pots are still a bit wide in range. They too might be changed to 10 K pots at a later date. But this also is a matter of taste. You might want to change some things to your own liking anyway.

4.2.3 The individual outputs

I chose simple chassis mounted single female jack outputs. But again it´s up to you. You can even choose Cannon type connectors. Now wouldn´t that look fancy / professional?

4.2.4 The interface connectors

I had enough old printer cables lying around so I simply choose standard 25 pin parallel printer connectors.

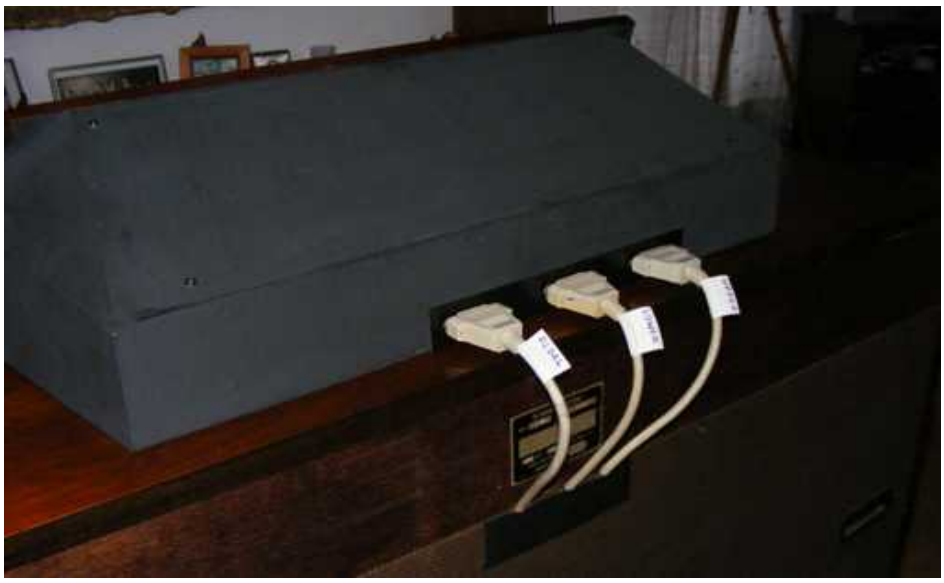

Fig. 3: My solution for connecting the controller box to the instrument. Every 25 pin connector carries the signals to and from on of 3 individual Orchestra Sections.

4.3 Hooking up

4.3.1 Wiring the controller box

Want to hook everything up?
Now it get´s complicated.
The only way to keep track of what your doing is to work very consistently. I color coded all the available connections. In other words: In every synth section the same colors where used for the same signal paths.

You'll find my wiring table below. My choices where determined by the 25 pins available per section, so this became the basis of the whole wiring approach.

Notes:

- For all the pots you in theory only need 1 lead line for the voltage feed from the preset matrix into the controller box. As a compromise I decided to use 3 individual leads (1 per subgroup) to make sure the line had enough capacity. Remember that a wire needs to let enough “juice” through it to feed the rest of the system. It could be that one line would have been enough but like I said before I am not an electronics engineer so I stayed on the safe side.
- Within the original preset matrix every branched line is led through an individual diode to avoid feedback effects. To repeat this faithfully in the new situation would have meant using 1 lead per pot plus even bigger connectors plus even more soldering. In the end it turned out the 4 separated feed lines with their individual diodes per ``group`` work just fine.
- The same actually applies to the waveform switches. So it could be sufficient to use only one feeding line in stead of the 3 mentioned in the table. Two pins can then be made available to lead other signals though, for instance for the individual outputs.

E-180 CONNECTOR LAYOUT

AS SEEN ON WIRING-SIDE OF FEMALE CONNECTOR

Color	Function
BLACK	10 V FEED 1 (FILTER)
BROWN	VCF = LOW PASS
RED	VCF = HIGH PASS
ORANGE	VCF = LOW RES.
YELLOW	VCF = HIGH RES.
GREEN	10 V FEED 2
BLUE	VCF = INIT. LEVEL
PURPLE	VCF ATTACK LEV.
GREY	VCA SUST. LEV.
WHITE	15 V FEED 1
PINK	VCF ATTACK
LIGHT GREEN	VCF 1 ST DECAY = DECAY (PANEL)
BLACK/WHITE	VCF 2 ND DECAY = RELEASE (PANEL)

Function	Color
15 V FEED 2 (VCA)	BROWN/WHITE
VCA ATTACK	RED/WHITE
VCA 1 ST DECAY = DECAY (PANEL)	ORANGE/WHITE
VCA 2 ND DECAY = RELEASE (PANEL)	GREEN/WHITE
WAVE 1 FROM E 70	BLUE/WHITE
WAVE 2 FROM E 70	PURPLE/WHITE
WAVE 3 FROM E 70	RED/BLACK
WAVE 1 TO E 70	ORANGE/BLACK
WAVE 2 TO E 70	YELLOW/BLACK
WAVE 3 TO E 70	GREEN/BLACK
	GREY/BLACK
	PINK/BLACK

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Fig. 4: This table shows how I wired the 25 pin connectors. The color coding in this table became the basis of the whole wiring approach.

4.3.2. Entering the beast

When you are ready with connecting the controller box things really get dangerous. You now have to go into the belly of the beast itself. So first bite away everything what still is left of your nails an then get on with the most difficult bit.
First open the lid on the top of the E70. The screws to release the lid are mounted left and right at the front of the instrument, just between the lid and the sliding cabinet cover.
You actually do not have to enter the rest of the instrument (that´s a relief!). It does however help to also remove the back cover from the organ. That makes it easier to get to the circuit boards.
Now open the sliding cover and take it out of its rails. This actually is now perfectly possible without unscrewing anything else. Another small bonus.
Because a lot of work has to be done inside the machine I decided to still get rid of the lid altogether. You then also have to disconnect the instrument lights which are build into the lid. If you want to do that to you will however have to make sure you isolate the lighting cables. You do not want to risk shortcircuiting something in there when you switch on the instrument regularly to check or measure something during the modification process.
Now walk to the backside of the instrument and look inside. It will take some time before you loose the ensuing dizziness. My god, it´s full of wires and electronics!
As soon as your vision drifts into focus again you will see an oblong metal box mounted at the left. That´s the digital boards section. And a very interesting section this is. The oscillators are for instance housed here.
But you actually do not want to get near them at all. In stead you have look at the individual row of boards at the right. That´s where we are heading!
On the inside of the back wall of the organ there is a paper strip. It says which board is mounted where. So this will be your guide to find the correct board to modify.

Preliminary tips:

- Prepare yourself thoroughly for the next stage.
- Make sure all your tools are ready for use and place them within easy reach, albeit at a safe position.
- An extra lamp would be handy to find all the tiny parts and connections, although there is nothing better then bright daylight always is the best.
- Make sure you do not drop anything metallic (for instance solder residue or wire clippings) into the instrument.
- I normally took the correct board first and covered the rest with a plastic table cover. This provided a working surface directly above the board rack.
- To make sure no foreign objects get in clean everything up every time you want to start up the instrument.
- Stay focused at all times. Better to stop working as soon as your concentration breaks then to make a mistake because you are too hasty or are getting tired. Whatever time this will take, it will take.

4.3.3 Connecting the waveform switches

Look for the TPS boards. There are 3 of them. TPS1 for the upper keybaord synth (Orchestra) section, TPS2 for the lower keyboard synth section and TPS3 for the pedal synth section
The TPS boards control general settings such as waveform, decay, gain and octave transposition. For us the waveforms are the important ones.
We´ll start at the TPS1 board. This controls the settings mentioned above for the Upper Orchestra sounds.
Take a look at the circuit diagram. The Funny2 switch directs a voltage to the 18 (61´) terminal. The cable leading to this terminal has a violet color
Following this line you can see that it is connected to diodes D119, 120 and 121.
For us the D119 diode is important. This sends the according voltage to the R3 terminal, triggering the 3rd waveform only, being a narrow pulse.
What can we deduce? That Funny II only uses a narrow pulse wave and does not trigger the 1st waveform (sawtooth) via terminal ST and the 2nd waveform (square) via terminal R1.
Now we want to change that. We want to be able to select whatever waveform or combination of waveforms we fancy.
For this purpose we already built the 3 switches into the controller box.

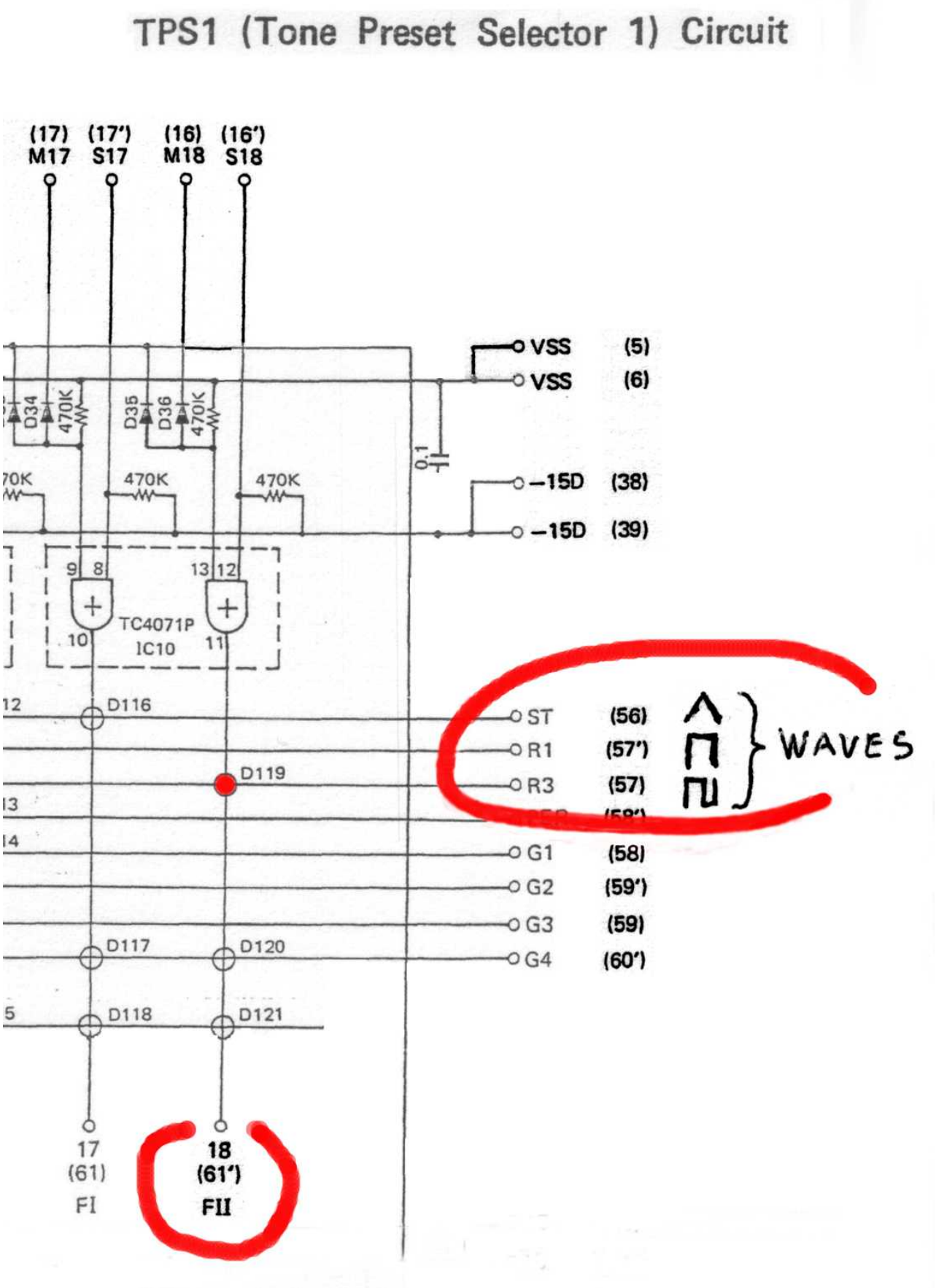

Fig. 4: The part of the TPS1 circuit diagram that shows the original layout (see paragraph 4.3.3 for what you have to change).

This is what you must do:

1. Look for diode D119 on the circuit board. Of course this is not numbered as such so you will have to find it by following the signal paths from the terminals.
2. Cut through the connection between the diode and the board AFTER the diode. Do however make sure you leave as much of the wire going out of the diode itself as possible.
   You have now disconnected the existing fixed signal path.
3. Solder a cable to the diode, leading to all the three switches for the Upper Orchestra waveforms as placed in your controller box.
4. Solder the cable coming from the other side of the Upper Orchestra **sawtooth** waveform switch in your controller box to terminal ST.
5. Solder the cable coming from the other side of the Upper Orchestra **square** waveform switch in your controller box to terminal R1
6. Solder the cable coming from the other side of the Upper Orchestra **narrow pulse** waveform switch in your controller box to terminal R3.

Phooey. 1 Done, 2 left.
Now repeat the same operation on the TPS2 (Lower Orchestra) and TPS3 (Pedal Orchestra) boards.
Be aware that not everything is exactly the same.

- On the TPS2 board the voltage input from the Funny II preset is connected to terminal 12 with a pink cable and the D103 diode has to be severed and reconnected to the waveform right switches.
- On the TPS3 board the voltage input from the Funny II preset is connected to terminal 12 with a pink cable and the D84 diode has to be severed and reconnected to the waveform switches.

If you did the above correctly you will now be able to select the waveforms of all the Funny 2 presets by pressing the appropriate switches on your controller!

4.3.4 Connecting the pots

At last we are going to find out where those damn preset matrices are.
Look up the TPR boards. This time there are 4 of them. TPR1 and TPR2 for the upper keyboard synth (Orchestra) preset matrix, TPR3 for the lower keyboard synth preset matrix and TPR4 for the pedal synth preset matrix.
The upper orchestra Funny II preset is controlled from the TPR2 board, so you can leave the TPR1 board well alone.

Have a look a the TPR2 circuit diagram.
What you will see is that the lead from the Funny II preset is led via terminal 12 (13) through transistor 24 and transistor 12. After these transistors the signals are fed to the different output terminals via a diode and a set of fixed resistors. You will have to replace the fixed resistors after diodes 137 to 146 with pots.
Note that no resistors are directly connected from this feed to VCA attack and VCF first decay terminals. The minimum signal levels are controlled by a row of 2.2 K and 10 K resistors which run parallel to this signal path, just to it´s right. So when only a minimal signal input is needed no connection is laid directly from the preset feed line.

The outputs to the different terminals are in the following order:

Function	**feed voltage**	**pot**	**output terminal**
VCA sustain	-10 V	100 kOhm	ASL (12)
VCF attack level	-10 V	47 kOhm	FAL (13)
VCF initial level	-10 V	47 kOhm	FIL (11)
Resonance high	-10 V	47 kOhm	HQ (7)
Resonance low	-10 V	47 kOhm	LQ (8)
High pass filter frequency	-10 V	10 kOhm	HfO (9)
Low pass filter frequency	-10 V	10 kOhm	LfO (10)
VCA 2nd decay (release)	-15 V	100 kOhm	A2C (48)
VCA 1st decay (decay)	-15 V	47 kOhm	A1C (49)
VCA attack	-15 V	100 kOhm	AAC (50)
VCF 2nd decay (release)	-15 V	100 kOhm	F2C (51)
VCF 1st decay (decay)	-15 V	47 kOhm	F1C (52)
VCF attack	-15 V	100 kOhm	FAC (53)

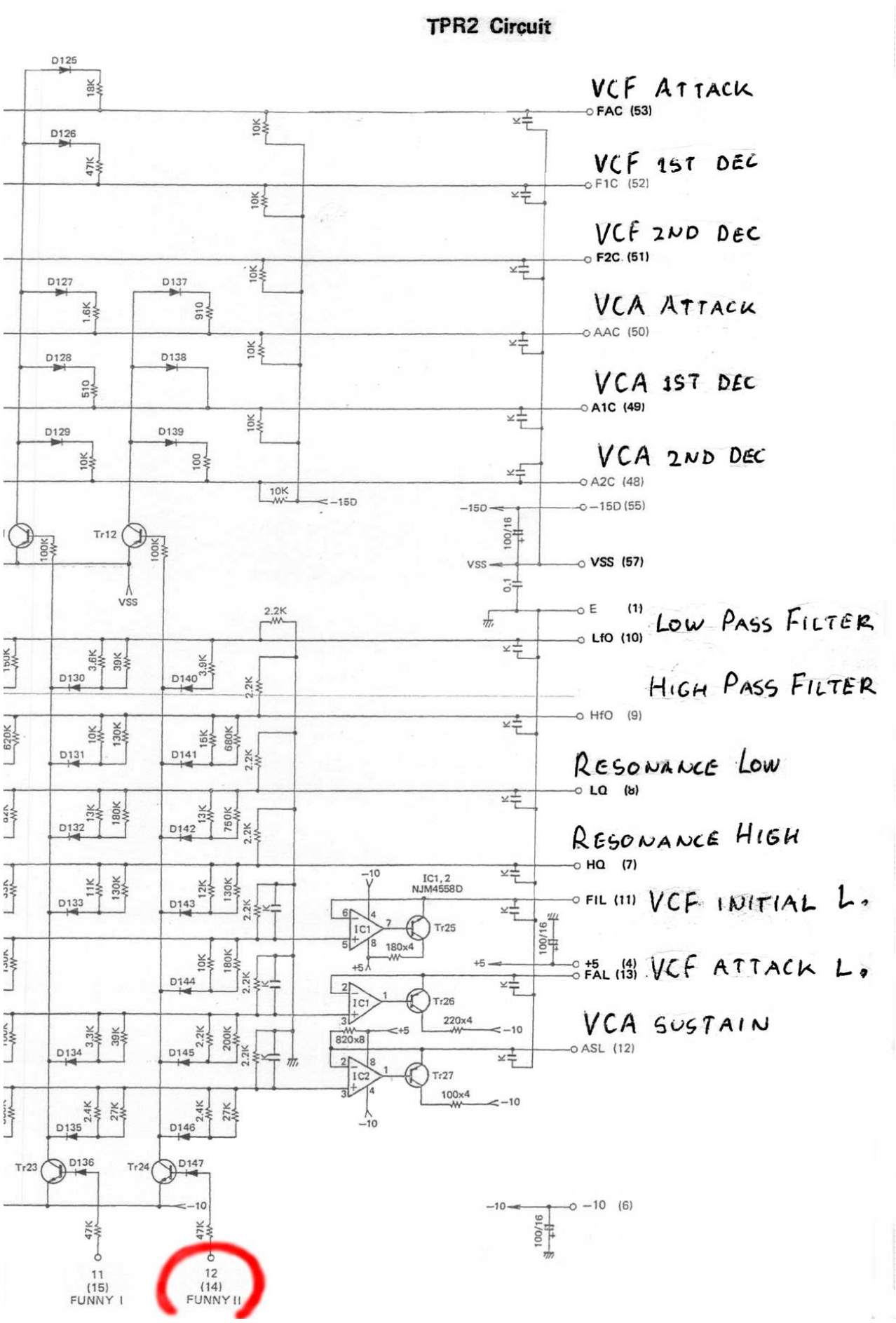

Fig. 5: Part of the TPR2 board circuit diagram. Now it gets really complicated!

Note that the synthesizer functions are not in the same logical order we have seen in paragraph´s 4.1 and 4.2.2. This has originally been done for practical technical reasons. Most important for us is that 2 voltages have to be fed to the pots, namely a -10 V and a -15 V signal. This is where our subdivision of our lead signal into 4 branches towards the controller box becomes logical. Two -10 V leads and two -15 v leads are used.

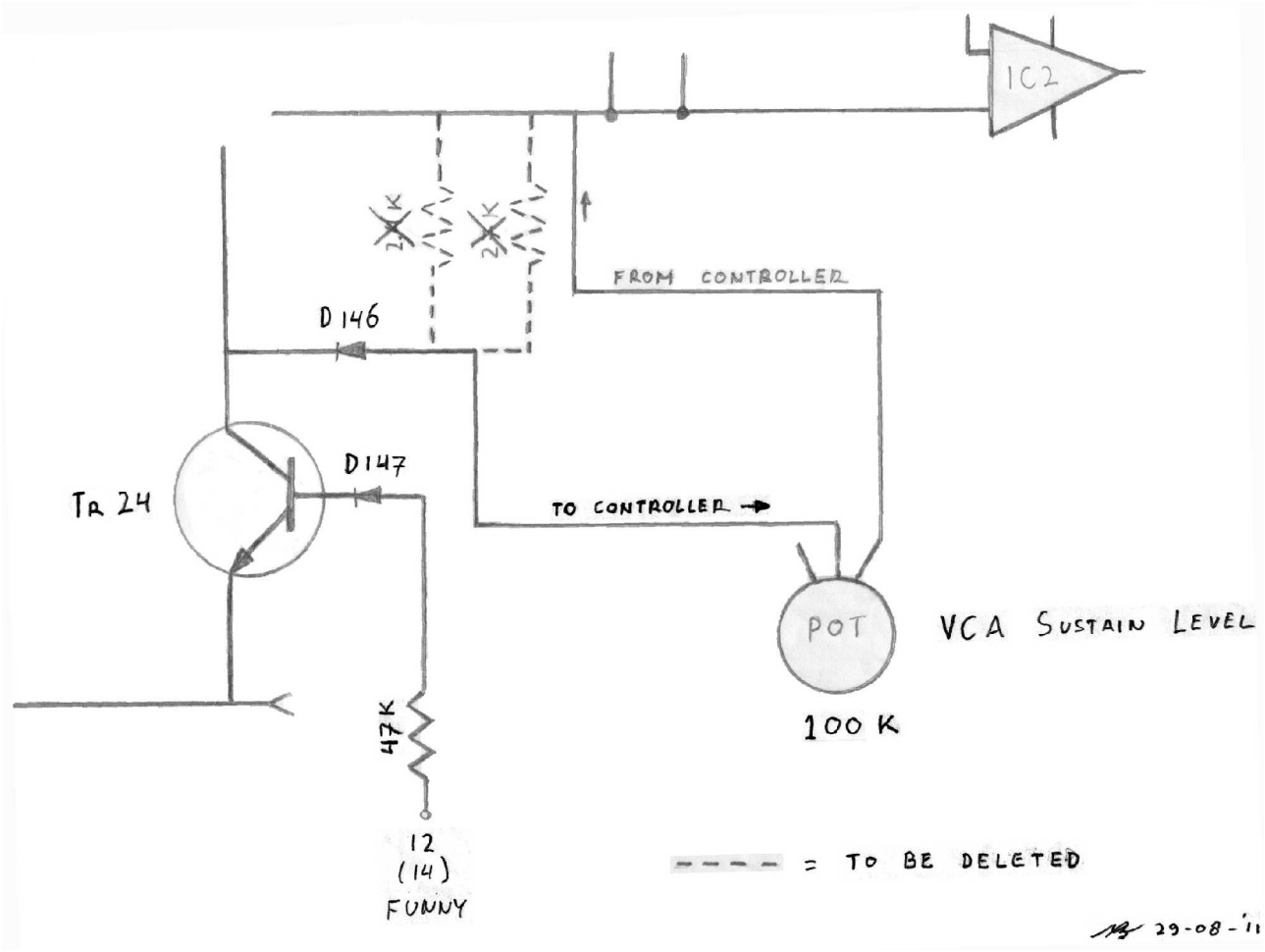

Fig. 6: example of connecting a controller pot after diode D146 (see text)

This what you must do (see Fig. 6):

7. Remove all the fixed resistor after the diodes 136 to 146
8. Look up diode D145 and D146, directly after transistor 24. Solder 2 cables from these diodes to the **10 V feed 1** and and **10 V feed 2** on the multipin connector (see fig.4). If you do not work with connectors you should contact them directly to the middle pin of the pots that have to be fed from this line.
9. Look up diode D138 and D139, directly after transistor 24. Solder 2 cables from these diodes to the **15 V feed 1** and and **15 V feed 2** on the multipin connector (see fig.4). If you do not work with connectors you should contact them directly to the middle pin of the pots that have to be fed from this line. You should now have established feed lines to all pots.
10. Now you must connect the outputs from all pots back to the TPR2 board. Contact the right pins of all the pots to the connection points on the circuit board to which the original fixed resistors where attached. Do **NOT** connect these signal lines directly to the output terminals because you will then skip parts of the circuit.
11. Now turn on your E70 and check out if all the pots in your controller box work (don´t forget to press the Funny II preset switches first!! You will be amazed by the new sounds your Upper Orchestra can now produce. You will however find that some pots work the wrong way around!
12. There is a easy fix for this. Write down all the pots that do not work in the proper direction.
13. After turning off the E70 disconnect the wires of those pots from the right pins and reconnect them to the left pins.
14. If you have done everything correctly all pot should now work correctly.

Again: 1 Done, 2 left.
Now repeat the same operation on the TPR3 (Lower Orchestra) and TPR4 (Pedal Orchestra) boards.

If things do not work properly you might have to get rid of some bad soldering connections. I had to search days for only 3 bad connections myself. So you might have to be very, very patient. If you cannto find any bad soldering check the cables themselves. You never know
If everything has gone right you should now have a fully functional Son Of GX with three fully programmable synthesizer sections. The only thing you still have to do is relabel the Funny II preset switches. I gave mine a black sticker with the text PROGRAM printed on them.

4.3.5 Connecting the individual outputs

In principle this is an easier job then the above so I will not get into as much detail.
But first it´s time for a little confession. At this moment in time (June 2011) I myself have not yet performed all the modifications necessary for this option. Female jack inputs for all sections are available on my controller box but not all have been connected yet.
At the moment I only use 3 signal lines.

1. The overall mono output signal as fed to the headphone output.
2. The main channel signal derived from pin 6 of the 11 pin Leslie connector at the backside of the E70.
3. The rotary channel signal derived from pin 7 of the 11 pin Leslie connector at the backside of the E70.

Now these might seem to be meager pickings. Do however not underestimate this setup. It provides you with the possibility to place the sounds in a very wide and natural sounding stereo field.

This is what I typically do:
I send the main and rotary signals to the mixer/recorder and pan them left and right. I then send the different synth (Orchestra) and organ (Flute) sounds through the main or rotary channel to my taste, just like one normally chooses which channels go through the rotary channel or not.
The headphone signal I send to a third mixer/recorder channel and typically pan that to the middle.
And here comes the trick. I then decrease the low frequencies on the left and right channels and add low to the centrally panned third channel.
You now have got a sort of Bose Accoustimass setup.
You can further add different effect settigns to the three channels, for instance reverb and stereo delay.
Another dramatic effect is to send the Orchestra and Flute sounds of the same manual to different outputs.
The sound get´s wider and wider and wwwwwwiiiiiiiiiiiiideeeeeeeeeerrrrrr!

But what about the promised real individual outs!
Now this is what I plan to do soon.
Before being summed together a lot of the sounds in the E70 are actually generated individually. They are put together on the VE circuit board but can be intercepted from it's connecting terminals.

- The UAI (11) connector receives the Upper Flute (organ) attack signal
- The UFI (13) connector receives the Upper Flute (organ) main signal
- The UVI (14) connecter receives the Upper Orchestra (synth) signal
- The LAI (10) connector receives the Lower Flute (organ) attack signal
- The LFI (16) connector receives the Lower Flute (organ) main signal
- The LVI (17) connecter receives the Lower Orchestra (synth) signal
- The PEI (62) connector receives the combined Pedal signal (although it must even be possible to find the 3 individual signals for the Pedals elsewhere)

5. Soundmatters

5.1 What does it sound like?

Talking about sound is always subjective. One thing is certain however: If the original E70 sounds good, and it surely does, then the Son Of GX sounds glorious!

Modern hard- or software-synthesizers often have presets that do not properly use all their possibilities. Ina comaparable way preset analog synthesizers always stayed on the save side. Normally a row of strictly imitative sounds (brass, wood, string, bass) was followed by one ore two real synth sounds to satisfy the novelty effect.
Things are the same on the standard E70. The sounds are even more traditional then the CS80 presets. It´s the warmth and depth of the sounds and the possibilities to generally adapt them by layering, filtering, detuning, octave selection, etc. that make the instrument attractive.
Now what happens such an instrument becomes fully programmable? It seems like it gets rid of a cold. No longer is it only restricted to sounds that only please the regular keyboard or organ player. Suddenly more extreme settings are possible.
And boy can a modded E70 scream. Who ever said that Yamaha filters can´t self-oscillate because they are only 12 dB? Crank up the resonance controllers and the thing bites back at you (Look out for them speakers, me matey!).
Furthermore you get full access to Yamaha´s typical filter envelope generator layout which has often been misunderstood and underestimated (also see my CS80 article).
It´s analog heaven!

5.2 So is it a poor mans CS80?

As I already mentioned it has been suggested that a E70 is so similar to Yamaha´s CS80 that you could call it a non-programmable alternative, for which you pay normal money in stead of the ridiculous prices a CS80 nowadays commands.
Indeed an E70 can sound a lot like other big Yamaha´s analog polyphonics. But is it true? Is the E70 a CS80 in disguise?
I wish there was an easy answer to this question.
Well basically there is:
No, it´s not a full equivalent to the CS80! There are strong similarities and these indeed go even further then the CS80 type colored preset selector buttons suggest. It is clear that these are children from the same generation. The roots of both the E70 and the CS80, together with a lot of other Yamaha gear, indeed go back to Yamaha´s first true venture into synthesizer technology: the GX1.
Describing this lineage and the similarities between the E70 and the CS80 would take a lot of time. Let's take a look at the differences in stead.
So what are these differences? Some of them are so obvious I will not spend much time on them here. Off course it´s clear the E70 or it´s professional equivalent the EX2 are organs while the CS series synths are fully programmable synthesizers.
But when you look below the lid the E70 is not 2,5 non-programmable CS80´s. There is a very important difference.
Now prepare yourselves for a shock.
The E-series orchestral voices are not analog! They are based on hybrid technology! In fact the oscillators are digital! The horror!
The waveforms in the P.A.S.S. (Pulse Analog Synthesis System) engines are stored on a chip as wavetables.
So, all you analog anoraks unite! This is proof the E/70 is just a dirty organ after all!
Well, believe it or not, those digital oscillators actually are a sort of blessing. There are two reasons for this.
First off all: One thing about seventies polyphonic synths wasn´t so nice at all. They where a troubled lot as far as staying in tune was concerned and the Yamaha´s CS80 was among the worst of them all. They need at least half an hour to heat up and even then the smallest whiff of ambient air will send them into a shiver.
Worse still: A CS80 which is moved around regularly has to be fully tuned every few months or so. The retuning process is a complicated job that includes recalibrating endless rows of tuning pots inside the beast (see my CS80 article for further tales of horror).
So it´s actually a good thing the E70 has digital oscillators. It stays in tune forever!
Secondly: Let´s be honest. The E70 sounds less distinct then the CS80. Not only are the oscillators digital but besides sawtooth and square waveshapes the E70 only provides a single narrow width pulse in stead of PWM (Pulse Width Modulation). Furthermore the CS80´s oscillators are of a quite special charged pump type (Thank you Scott Rider for finding that out). This gives them their very distinct sound.
Once you know that sound you can detect a CS80 in the densest of arrangements. Believe it or not, the first time I saw the ``Last Waltz`` by The Band I heard the CS80 before it became was visible.
Even it´s tuning instability is part of the CS80 sound. It makes the synth almost like a living creature with a will of it´s own!
But a synthesizer sound does not only depend on the quality of its oscillators. The rest of the E70´s voice architecture is still very analog Yamaha indeed. First of all there are 2 filters, a low and high pass, both with individual resonance controls. Furthermore there is the typical Yamaha 5-stage filter envelope generator. And

you can couple the upper and lower orchestra voice on an E70, which provides you with two fully independent, layered sounds. That´s why the E70 can still sound like a CS80.
But there still is an audible difference. Nothing quite sounds like a CS80. But the disadvantage of this is that a CS80 always sounds like a CS80. And here comes another shock. Even though a fully programmable E70 like the ``Son Of GX`` actually has fewer programmable parameters the basic sound is still more versatile then that of a CS80. The Son Of GX can sound very analog but the digital precision of it´s oscillators also enables it to emulate an early eighties digital wavetable synth quite well. So it actually provides a best of both worlds!
On the other hand the CS80 runs rings around it when it comes to effects sounds. But there is a rather good cure for that. I recommend adding an Eventide Modfactor to your Son Of GX's output. This even has a stereo ringmodulator on board. **Bzooooooingaaaarhburble**!
There is one big disadvantage however that no smooth talking will paint over. And that´s the keyboard. The CS80 has a fully velocity and polyphonic aftertouch sensitive, weighted keyboard. In other words. The velocity with which you strike a key and the force with which you hold it down is translated per note. It´s the ultimate in keyboard expression. It's the best conventional synthesizer keyboard I have ever encountered!
And what does the E70 have? No velocity or pressure sensitivity at all. You can use the foot pedal to control the overall volume and the filter of the upper manual voices. That actually works quite well but it is not comparable by any measure.
Furthermore you can wiggle the keys of the upper keyboard form side to side to add a more natural vibrato then the one provided by an LFO. But that function doesn´t work on any of the E70´s I´ve laid my hands on!
Anyway: Compared to the CS80´s keyboard these facilities are just crutches. So in this respect the E70 doesn´t stand a chance, even after a Son Of GX mod.
So what is my verdict? A fully programmable ``Son OF GX`` is almost is the ultimate in analog polyphonic synthesis. Only an equally modded, fully programmable EX1, with it´s extra monosynth, could top it (So hand me over yours so that I may do my magic again!). Or a GX1 with programmer box. But who can afford a GX1, which, by the way, is just as unstable in the tuning department as the CS80.
But what if the CS80 is then still the ultimate in polyphonic expressiveness! A true ``Son Of GX`` almost makes it easy to live without THAT keyboard. 2 fully programmable 2 oscillator polyphonic synthesizers and 1 one fully programmable 2 oscillator bass synth in an extremely ergonomic package do a lot to compensate any flaws. And don´t forget the extra organ sections. Hell, if you couple the Pedal Orchestra to the Lower Orchestra, add organ and turn on the detuning (Celeste) effect on both, you actually hear the sonic equivalent of 8 oscillators per voice. And one could even state the extra footage's in the organ sounds are more or less equivalent to extra sub-oscillators. So is it any wonder you hardly miss the CS80's full PWM facilities. This setting can burn down a Moog Taurus any time!
Furthermore all groups can be processed independently and mixed down in glorious stereo. And there also is a versatile arpeggiator on board. Even some cheesy drum rhythms and presets patterns can be added and synchronized.
So who could ever complain?
Now if I only had a spare corner in to which I could fit both the CS80 and my Son Of GX at a 90 degree angle. That would even make a GX1 blow out its brains. BRRRRRR!

6 For further information

Background Info: Old Crow's synth shop CS 80 pages
http://www.oldcrows.net/~oldcrow/synth/yamaha/cs80/index.html

Background info on: Old Crow´s on CS in the E-series Electones:
http://www.electone.com/blog/?f=view&i=236

Rediscovering the E70: Flametopfred on YouTube
http://www.youtube.com/results?search_query=flametopfred&aq=f

Getting there first: Robert Skerjanc's E75 mod
http://www.skerjanc.de/E-75.htm

Me to said the fool: My demonstration video's on YouTube
http://www.youtube.com/results?search_query=marcjeparkje&aq=f

Marc Brassé
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