

# SGX V2

Adding a third manual, including an  
aftertouch sensitive solo synthesizer  
and extra organ section,  
to the Son Of GX



Fig. 1: It's alive!

by Marc Brassé

## 1 Part 2 (er 5?): The analog oscillator strikes back

Those who read this might have, or actually should have read the first part of this Yamaha E-series customization guide. It explained how specifically an E70 can be turned into a fully programmable super-synthesizer, although the knowledge will also be applicable to all other top of the range E-series Yamaha Electones, such as the EX-1, EX2 and E75.

The whole Son Of series of procedures turns one of these wondrous organs into a sort of GX1 with digital oscillators. The ultimate choice would be to start with an EX1 because it, just like the GX1, it also has a third manual driving an analog monophonic solo synth. A fully programmable EX1 would therefore actually be the ultimate replacement for the legend. Alas EX1's are equally thin on the ground and if found tend to cost a bundle of cash.

So what must a boy do who is still dreaming of going the whole way? Just take the next step in developing the ultimate poor mans GX1 equivalent.

The initial idea is simple enough: Just slap an extra monosynth on top of your SGX V1.

So I did and this article concerns itself with this second stage in the conversion which I now tend to call SGX V2. SGX obviously stands for Son Of GX but could just as well mean Super GX and V2, well that hardly needs any explanation at all, now does it? For those who still insist: If not a pun on the use of the letter V in software versions it could indicate that the whole thing now has really gone ballistic (V2 = first ballistic missile. Get it? Oh, why do I even bother!)

Enough with the silly introductions. Let's get (a bit more) serious. Would any solo synthesizer do?

Theoretically: Yes. Why not simply put your average monophonic synth on top of your E-series and be done with the whole thing. Well, that would be too easy, now wouldn't it?

Better to stay in the spirit of things. What is the actual sense of building a Son Of GX in the first place?

Glorious multi-manual organ ergonomics aside almost every multi-timbral synthesizer from the 1980's and upwards can do the same work. The whole idea is more to stay faithful to the GX1's conceptual spirit and use E-series period technology to get there.

The most obvious choice would therefore be to use another instrument from the 1970ties as a donor, better still a Yamaha Electone.

The choice actually was no that difficult at all. Had I not first gnarled my teeth on the whole concept by making the solo synthesizer section of a Yamaha CSY1 organ programmable? So why not start with a CSY again?

It is even said that the CSY actually hit the market before the GX1. At any rate: The CSY is also literally carrying GX1 technology under its hood. It uses exactly the same enclosed VCO, filter and envelope generator boxes. So how more period, Yamaha and close to the original can one get?

## 2 Better even then the original?

Well, I actually used a CSY2. It did no longer carry a enclosed oscillator module. In stead the oscillator is openly accessible on a component level, although the filter and envelope generator modules still survived. I guess they must have been running out of those potted GX1 oscillators.

On the outside, say on the user level, the CSY2 is actually surprisingly similar to the CSY1. So much in fact that they could just as well have called it the CSY1 V2 (hardihar). For all intents and purposes this guide concerns itself with both versions, especially since one does not actually have to go near the VCO to perform the necessary mods.

So far so good. I had thus chosen my donor instrument. All the synthesizer electronics are mounted on the under- / inside of the CSY's upper lid so one could actually decide to only implant that top lid together with the keyboard and the existing programming panel and tie it in with the E-series power supply.

But what do you know? I still thought that would be too easy!

There is a very musical reason for this stubbornness though. If one only wants to add a CS type solo synth one can just as well start with a Yamaha SY1 or SY2 synthesizer. They provided the same technology in a stand alone form and thus are the first Yamaha instruments that could claim to be "true" synthesizers.

Interesting trivia: The SY2 was actually more advanced then the SY1 because it had more user definable parameters. For our goal both would however again suffice since we would be eliminating the difference in programmability anyway.

Another reason to not use a SY is that it nowadays costs a lot more to get hold of one then of a complete CSY, courtesy of the whole overblown analog synthesizer revival.

But I digress. The most important reason to use a CSY is the following: A CSY actually is more sonically versatile because one can use it's organ section as an extra oscillator section. OK. That second section then does not have filters, nor E.G.'s and thus no full programmability. The Yamaha developers have however been so nice to include organ stops with different waveforms (something which the upper E-series models

actually do not provide. Everything is strictly sine wave there).

Most synthesizer fans actually tend to pull up their noses at such bonuses but think about it: One of the strongest tricks of the later CS-series synthesizers was that they offered an extra sine wave that could be tied in after the filter to add more bottom end to sounds that had been thinned out by the (equally typical) CS-series high and low pass resonant filters. Adding a parallel organ oscillator section to a (C)SY synth actually does the same. You are then only still missing out on a VCA envelope.

So how does a CSY with the analog oscillator slightly detuned and the organ mixed in at a slightly lower level sound? Well, much more versatile and fatter than a single oscillator SY. Add to that a choice of alternative, equally mixable waveforms (saw and square besides the typical sine) and paying more money for a SY actually becomes a bit of a laughable propositions.

One step further even is to think of that upper organ as an extra polyphonic section. You can play chords on it, even layer those chords with a single analog top voice. Again, who would actually want to leave such options behind?

And theoretically this state of affairs can even be topped again. What about a CSY in which one can run the whole organ section through the filters and VCA of the analog synth? Then one actually gets a paraphonic poly-synthesizer. That is a bit of a misnomer actually. A synth is either monophonic or polyphonic but paraphonic is the phrase that is used for synthesizers which can play more than one voice but send these multiple voices through one single filter / VCA path.

So that became my actual plan: To not only implant the CSY solo synthesizer into the Son Of GX but to also retain the upper organ section of the CSY!

For practical reasons I will call the resulting contraption the CSY 0.5 from now on. What is a single manual CSY when compared to a type 1 or 2? A type 0.5! Get it?



Fig. 2: This is the first goal on this journey: Building a reduced, standalone CSY 0.5 that will serve as the GSX V2 solo section.

### 3 A few warnings first

I would like to start off with a few warnings / reminders:

1. On both my old Yamaha organs the amplification broke down quite quickly after I started using them regularly. In my SGX this collateral damage was caused by a faulty power supply in which a mylar capacitor burned through.  
Having repaired the power supply and being more synthesizer oriented anyway you can of course live very well without an amplifier if you connect it directly to an external source. But you do lose the option to play without headphones and / or use the rotating Leslie-effect speaker. So it's much better to prevent such problems in the first place.  
Therefore my first tip is to replace all parts in the power supplies of your machines that are prone to aging.

2. The level of skills needed to perform the jobs mentioned in this second installment are actually higher than those required for the first guide. Not as much as far as electronics are concerned but more when it comes to general dexterity, mechanical skills and especially insight. So the user of this manual is not only supposed to have the basic skills to perform such operations but at times also to determine the next necessary step him-/herself.
3. For similar reasons it is more important than ever to work with discipline. ALWAYS take the conversion process one step at a time. It's the only sure way to keep track of where you are / left off last time. I know of at least one E70 which someone started to rip apart to leave the job after a short time, clueless where to go on. Why I know about this particular one? Because the remains of this instrument now form my spare parts stock. Nice for me but sad for its previous owner and his formerly functioning, rare E70.  
So if you are enthusiastic: Great! Do however not make me responsible for that gigantic pile of loose parts in front of you. Why? Because I just warned you (again), dude!

#### **4 Removing the superfluous stuff**

Well (gulp) the CSY's organ section is actually a rather entangled proposition. It generates organ tones for 2 keyboards, a set of bass pedals and also provides drum patterns and a few basic accompaniment functions. All these functions are however not neatly packed on to individual boards but tend to run criss cross through each other.

What therefore has to follow is a very empirical process. A cherished Internet pal of mine has actually called it the Artful Dodger school of electronic engineering. I do not think he actually intended it as a compliment but he surely hit the nail on the head.

So many little jobs have to be performed that it is virtually impossible to reconstruct every little detail in this guide. I would actually have to do the whole thing again to remind myself of every step and document it with pictures, leading to a tome that would become as thick as an ancient telephone directory.

In principle my approach was however deceptively simple. I "just" decided to eliminate all functions that were not practical to retain in a more compact setup but actually hardly touched the electronic parts. Thus I started to remove all parts that would not be retained from the donor CSY.

These are:

- The lower keyboard
- The bass pedals
- The drumbox
- the accompaniment options
- The amplification system (amplifier plus a speakers)
- All controls configuring the aforementioned sections.

I did however not only remove these parts but also all the wiring leading to the specific sections in the CSY circuit boards. So whole wiring harnesses had to be disentangled and all the superfluous wiring taken away up to the board connectors.

In other words: A strict diet was undertaken. No, let's call it an electronic equivalent of a liposuction. Excess parts and bits of wiring kept flying in all directions until the remaining instrument came to look like a thing that would never function again.

One very, very important prerequisite was to always check if what I was about to remove did not influence the functions I wanted to retain. So I monitored the functionality of the upper keyboard, analog synth and organ section during each step.

The modus operandi therefore is:

1. Disconnect the next superfluous controller / section.
2. Check if all the sections that need to remain still work.
3. Only if they indeed do make the change permanent by removing the associated parts and wiring.





**Fig. 3:** This picture shows how several parts where moved into the upper part of the housing. For instance: the power supply(left), reverb spring (middle), power switch and outputs (upper right).

Again: Te actual electronics are so entangled that splitting them is next to impossible. So electronically speaking our trimmed CSY 0.5 is theoretically still able to produce drum sounds and such! If anyone would ever be be so crazy to turn the whole operation around again that is.

## 5 Redistributing controllers and outputs

The next step was to move the few lower placed controls that had to be retained in the chopped version to the upper section. These where:

- the on/off indicator light
- the master volume pot
- the reverb pot (replacing the original lever with a conventional rotary knob)
- the flute / orchestra (= organ / synth) mix pot (again replacing the original lever with a more compact knob)
- the output channel switches (for sending both sections to the main or the rotary channel output)
- The external insert jacks and headphone output assembly (formerly placed below the right side of the lower keyboard)
- The Leslie type additional outputs (formally fitted into the lower backside of the instrument)
- the on-off switch (formerly positioned beside the lower keyboard)

If you have a closer look at Fig.2, 3 and 4 you will be able to pick out most of my solutions for these details.

## 6 Further real estate movements

Concerning the **power supply**: One basically has 2 options to feed the remaining CSY electronics:

1. To get the power from the E70's original power supply, which is quite a sturdy unit and should thus be able to cope.
2. To move the original CSY power supply into the section of the housing that will be retained.

I personally decided on the latter for the following reasons:

- No extra electronic complications resulting from power consumption demand interferences will occur.
- The CSY 0.5 top section actually becomes a stand alone unit that can eventually also be used individually (Who always knows what the future brings?). Furthermore having a detachable solo section is benefit if the instrument has to be moved. Welding / wheeling an original E70 through the vicinity is already more than enough trouble!

Luckily there is just enough room in the upper part of the original housing to move the complete, relatively compact original CSY power supply there. I installed some metal base plates to provide shielding between the power supply and the audio electronics to make sure this did not lead to interference. After the operation a last audio check ensured that hum had indeed not increased.

I also moved the **reverb spring** from the lower part of the housing, near the bass pedals, to the upper part.

Lastly: One cannot just remove the CSY's **volume pedal**. So many signals are actually led through it in parallel that discarding it would be small project on its own. Instead I decided to keep it fully functional. I just rerouted everything into a lengthened combined cable and connected that to the CSY 0.5 with a multi-connector, thus again enabled detachment of the CSY 0.5 from the rest of the combo.

## 7 Trimming the housing

By now I had ended up with a still more or less complete CSY housing containing a single manual CSY 0.5. The picture in Fig. 2 was actually taken around this time. If you look at its lower portion you can see all sorts of tools laying around in the tray that used to carry the lower keyboard.

To make this new incarnation usable for its destined function the housing now had to be trimmed until only the upper casing remained.

This time my approach became a bit philistine. Normally one would have to remove all the electronics (again) and then trim the housing but, being rather confident of Yamaha's typical build quality, I decided to (more or less) carefully do this while everything was still in place.

Using a conventional saw did however prove to not be very practical. Both with a hand saw and a hand held electric one cutting neat straight lines can be rather problematical. Furthermore high impulse vibrations can damage the electronics. I therefore decided to use an angle grinder with a thin cutting blade instead.

The results were not pretty. Imagine walking down a regular street, hearing a lot of electric DIY tool whining, looking into a driveway, seeing a wide open garage door and watching dirty smoke billowing from it as if the whole building is on fire. That might seem like a bit of hyperbole but alas it is exactly what happened.

The pressed wood pulp of which most of the housing has been built really starts to glow and decompose when cut this way and the resulting smoke is dirty, unhealthy to the operator and very environmentally unfriendly. I therefore recommend not to recreate these particular circumstances and use a workshop that has an advanced air cleaning installation. Wear a proper gas mask while you are at it anyway. A normal dust mask is not sufficient because it does not hold back toxic fumes. Oh, and make sure the Environment Police is occupied elsewhere.

After this step we are however at last left with a fully operational, compact, single manual synthesizer / organ combo that only needs a stand alone amplifier or pair of headphones and a mains plug to be used.

## 8 Converting the top of the SGX V1

Where to place this contraption then? For playability the typical GX1 / EX1 solution of placing the 3rd manual directly above the 2 main keyboards is best. That would however mean that almost the whole existing programming sections for the E70's flutes and orchestras would have to be raised above our CSY 0.5.

Placing the CSY 0.5 on top of the E70's controls in stead would however still be acceptable form an ergonomic standpoint. So I actually decided to "wedge" the CSY 0.5 between the existing E70 programming panels and the programmer box (see paragraph 11 and further). In that case I would only have to build the CSY 0.5 into the top of the existing Son Of GX.

I thus removed both the SGX's upper lid and the rolling louvers. Basically the CSY should now fit directly on top but there where a few complications:

- The CSY 0.5 is was so deep that positioning its keyboard at an optimal depth would lead to a huge bulge at the backside of the combined setup.
- Furthermore the specific CSY controls and the SGX programmer box would then get rather far out of reach for a seated player.
- It was actually impossible to move the CSY 0.5 that far back because the original E70 housing carries a strong wooden beam its upper backside.
- Moving the whole CSY 0.5 forward gave a rather opposite set of complications: The extra keyboard and housing depths would then actually interfere with handling the SGX.

The solution consisted of 3 steps:

1. To move the beam closing the the E70's upper back side to a lower position so that the CSY 0.5 could actually rest on it with its back panel almost in the same plane as the E70's back. This did however mean that the E70's backside panel had to be cropped accordingly (see Fig. 12).
2. I also decided to move the full size solo keyboard 45 mm inside the CSY 0.5. The keys are thus still full size but mis a few cm of access where white keys and black keys sit beside each other. That might seem to be a rather big restraint but in practice it is not as bad as one might think. Because the keyboard is placed so high on the instrument one is not actually "bending into" the keys but already has a hand position in which such deep grips are seldom asked for. The resulting compromise is actually better then the cropped keyboard on the GX1 because the keys still retain their full depth and thus react as expected in every other aspect.
3. The CSY 0.5 is not as wide as the SGX V1 / E70. So I reused the outer sections of the original E70 cover to fill the remaining spaces (see Fig. 1).
- 4.

## **9 Mounting the extra volume pedal.**

I then mounted the CSY's volume pedal beside the E70's original one, thus providing separate volume pedals for the solo section and the total instrument. One can then for instance leave all the accompanying sections at full strength and use the extra pedal to add expression to the solo section only. Of course the speaker cabinet cover below the keyboards also had to be refurbished accordingly but hey, the result is looking rather good (see Fig. 1).

## **10 Feeding the CSY 0.5 combined output signal into the E70's amplifier**

One thing only remaining before we have actually added a fully functioning (although still not yet fully programmable) solo keyboard to the Son Of GX and it's a simple one: Connect the CSY 0.5's headphone output to the E70 external input under the right side of of the lower keyboard (It's almost as if Yamaha actually "foresaw" our need for this option). With it you can actually send the signal of your very own CSY 0.5 into the E70's amplification system. OK, you cannot send it into the rotary channel but that is only a minor restriction.

## **11 Rebuilding the the programmer box**

We are slowly getting there. Until now we have however still "only" added a trimmed CSY. The next step will be to make it fully programmable.

We start this part of the operation with adding add 2 more panel space to the P.A.S.S. programmer that had already been built for the original stage 1 SGX conversion.





Fig. 4: My Gawd! The programmer has become so wide that I had to rotate the picture!



One advantage of choosing the CSY is that its mono synth on needs the same extra programming controllers that were already added to the original SGX V1's orchestra sections. The typical Yamaha CS-class filter, VCA and EG controls can therefore be configured exactly the same. Which looks nice! I will not describe the whole operation in every detail here (see the first part of this customization guide for more information on that). The short version however is that one has to :

- widen the case
- redesign / reconfigure the control panel(s),
- mount an extra multi-pin connector in the back of the programmer box

I based my programmer's front panel on the E70's original music stand but had already used up most of it for the V1 version. In the mean time I had however bought an extra E70 in case I ever needed a parts donor. Thus I decided to also use its stand and build a version of the programmer with 7(!) panels in stead of 5. One panel would then contain the extra typical SGX filter and VCA controls for the monosynth / orchestra and the other for the additional synth controls, also moving the SGX's waveform selection switches there.

This led to an even more impressive control surface that became nearly as wide as the whole instrument (actually wider than the CSY 0.5 itself!) (see fig. 4).

The next paragraphs will concern themselves with the actual electronic alterations.

## 12 Turning the CSY 0.5 into a fully programmable synthesizer

So here we go again.

Open up the CSY 0.5 cover. At its left inside you'll find a board called SP1.

To repeat an old story: This single board manages most settings for the presets. What it basically does is provide preset voltages to set the synthesizer components (Filter, EG's etc.). A matrix of resistors is used to achieve this. What will happen if the fixed resistors for one preset are replaced by adjustable ones (= pots and sliders)? Then your synthesizer suddenly has a fully programmable channel. So basically every preset synthesizers has a programmable synthesizer in its heart. You only have to open up the possibilities.

Fig. 5 shows an enhanced functional diagram of SP1. Compare this to the original diagram in the CSY2 service guide.

This is what I literally did:

I chose the DOUBLE preset as my programmer switch because this preset actually is the only one using the mixed sawtooth plus square waveform which gives the fullest sound.

On the SP1 board one can simply remove all the resistors for this preset and replace them with wires that connect them to the new pots and switches on the programmer box via appropriate multi-cables and connectors. You can make your actual system as intricate as you like but as long as it is functionally the same as what you see under the DOUBLE switch the setup will function.

The pots are generally 100k. If I remember correctly I only used 50K for HI and LO resonance. Basically you can have a look at the matrix and see what maximum value is being used for a certain parameter. If the region you tend to regulate the pot in is still quite narrow you can use a non-linear pot to widen the most effective portion or even work with a pot and an adjacent fixed resistor if you want to get really surgical. Giving some pots a range that clearly goes higher than the highest preset values really "un-clogs" the monosynth. It changed the CSY from a cheesy organ expander with conservative sounds to an instrument that can be really moody and dirty.

But again. Whatever you do to improve the system the principle stays the same: You are replacing the fixed resistors in the matrix that belong to DOUBLE with variable ones.

So basically it's all just a matter of deduction and holistic thinking.

After doing this you can program the high and low pass filters and both EG's.

## 13 Additional solo synth functions

The Solo Orchestra programmer panel now contained the same controls as the other orchestra section panels but there were several extra functions which had not yet been included there. Therefore the left of the main control panels (second overall) gives access to some extra controls:

1. The waveform selection routings are hardwired on the PN1 board to which the preset switches are attached. The standard CSY monosynth only generates 2 waveforms (sawtooth and pulse). I added dedicated waveform switches for these to the left main panel of the programmer.

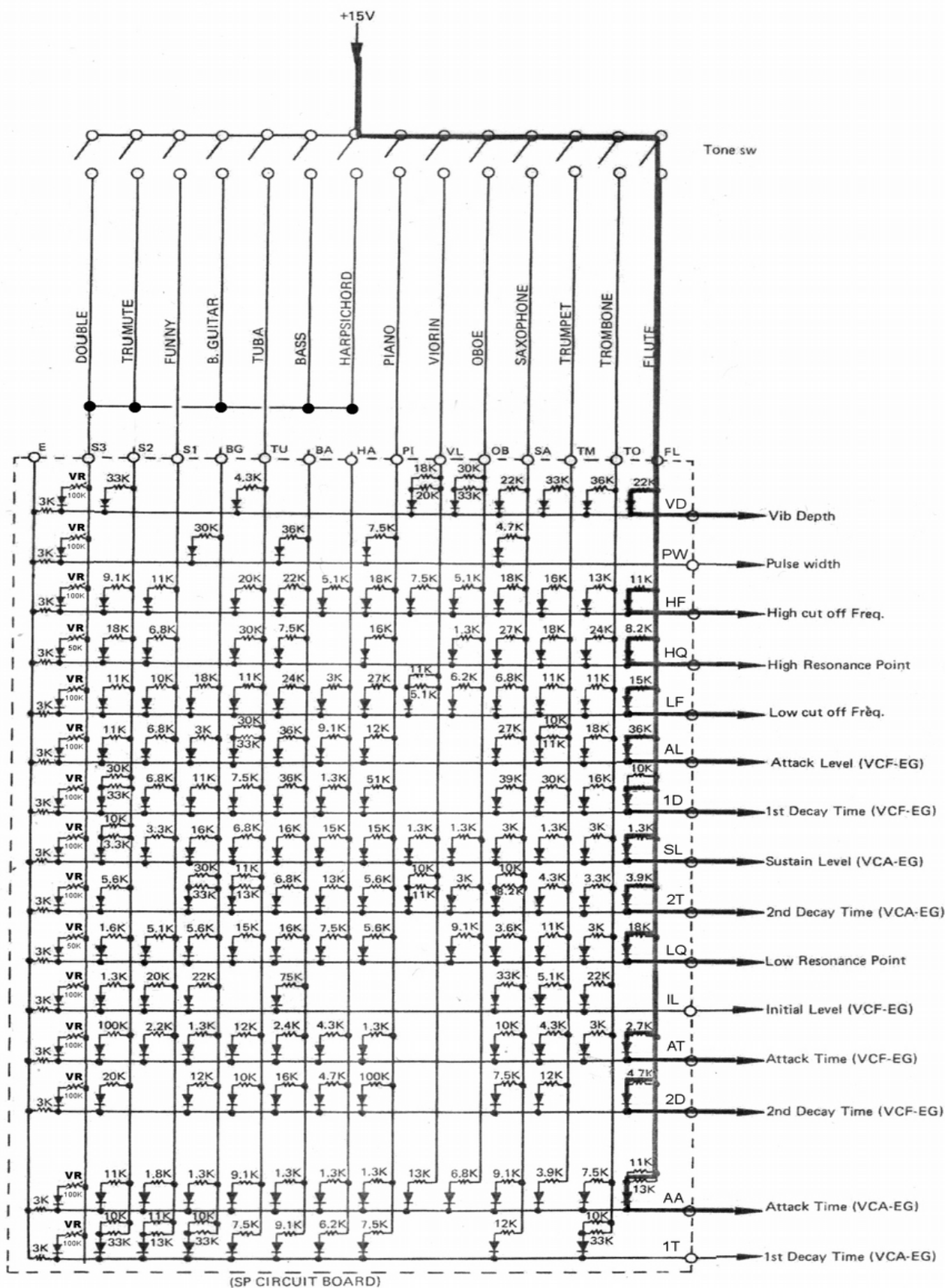


Fig. 5: All important modifications are concentrated in this diagram of the SP1 matrix board. The far left input column fed via the Double switch now sports variable resistors marked VR (= pot) (see paragraph 12). Furthermore 5 preset switches have been grouped to 1 input to enable routing of the different waveform setups to the same, now programmable channel (see point 5, paragraph 13). Remark: The voltage path for the Flute preset is marked with thick lines at the far right of the matrix.

* AA 1T 2T * * * * * * PW	AS SEEN ON WIRING - SIDE OF FEMALE CONNECTOR	VCF-MOD SW. RETURN TO S3 / DOUBLE	BROWN / WHITE	BLACK	10 V FEED 1 (FILTER)	*
		VCA - ATTACK	RED / WHITE	BROWN	VCF - LOW PASS	LF
		VCA - 1 ST DECAY = DECAY (PANEL)	ORANGE / WHITE	RED	VCF - HIGH PASS	HF
		VCA - 2 ND DECAY = RELEASE (PANEL)	GREEN / WHITE	ORANGE	VCF - LOW RES.	LQ
		SAW WAVE 1 FROM CSY	BLUE / WHITE	YELLOW	VCF - HIGH RES.	HQ
		SQ / PULSE WAVE 2 FROM CSY	PURPLE / WHITE	GREEN	(FILTER 10V FEED 2 + VCA)	*
		SUB OSC. SW. IN	RED / BLACK	BLUE	VCF - INIT. LEVEL	IL
		SAW WAVE 1 TO CSY	ORANGE / BLACK	PURPLE	VCF - ATTACK LEV.	AL
		SQ / PULSE WAVE 2 TO CSY	YELLOW / BLACK	GREY	VCA - SUST. LEV.	SL
		SUB OSC. SW. RETURN	GREEN / BLACK	WHITE	VCF-MOD SW. IN	*
		VCO PULSE WIDTH	GREY / BLACK	PINK	VCF - ATTACK	AT
		VCF-MOD SW. RETURN TO S1 / FUNNY	PINK / BLACK	LIGHT GREEN	VCF - 1 ST DECAY = DECAY (PANEL)	1D
				BLACK / WHITE	VCF - 2 ND DECAY = RELEASE (PANEL)	2D
		REMARK: FEED OF 10V TO VCO PULSE WIDTH POT IS TAKEN FROM 10V FEED 1 (BLACK WIRE)				

Fig. 6: This shows how the programmer is connected to the CSY 0.5 via a 25 pin connector. Note the coding at the sides being the same as the terminals on the SP1 board.



2. The CSY can however modulate the pulsewidth of the square wave. An extra pot has been added to set it. So although there seems to be 1 waveform less this setup is actually more flexible than that of the other, digital orchestra sections
3. The original DOUBLE preset on the CSY is the only one sporting a sub-oscillator. I also added a switch to enable adding this function to all the sounds created on the programmer.
4. The original TRUMUTE preset is the only one on the original CSY in which LFO modulation is applied to the VCF. A further special switch has been added to make this function freely available during programming.
5. To describe the mods that are needed to access all the different waveform and modulation permutations is quite complex. There however is a quick fix which I originally came up with for the monosynth of my Polcheesy 800 project. This is how it goes:  
See Fig. 5. Here not only the voltage feed from the DOUBLE preset is fed through the programmable channel but also those from the HARPSICHORD, BASS, BASSGUITAR and TRUMUTE switches. You then end up with 5 switches that provide almost all possible waveform and modulation permutations without actually having to change anything on the PN1 board. You can label these switches accordingly. Yep, you do indeed lose 4 more original presets but it surely is the easier method to get such access.  
The actual explanation: When only viewed in this diagram these re-routings seem to add nothing but since the actual switches are of a multichannel type they at the same time also take care of the waveform switching in other parts of the circuit. So you are still changing other things when you choose between these 5 switches.
6. The CSY generates portamento but since this function can already be freely set on the original instrument no extra controllers have been added.
7. The same applies to the already well developed aftertouch controls. Not much need for anything extra there.



Fig. 8: The new left main panel with the waveform selectors and additional solo synth controls on my own SGX V2. Point 5 in paragraph 13 however describes a much easier fix.

## 14 Wiring up the programmer

Fig. 6 contains the table I used for adding the extra 25 pin connector between the solo section and the programmer. One can see the actual connector in fig. 12.

I used much the same pins and wire colorings as with the other orchestra sections and even went so far to make the solution foolproof. If I did everything right putting this connector in the wrong input will mean that your solo orchestra panel will simply be connected to another orchestra section. You will of course also not get access to the extra solo synth parameters but at least you will not blow anything up either.

Note that the codes which Yamaha used on the terminals of the SP1 circuit board are also mentioned in Fig. 5 and Fig. 6. How convenient!

## 15 Crushing it up

Much, much more could still be done, until the whole contraption turns into a wall wide polyphonic modular system (Ever heard of T.O.N.T.O ?) but I decided to take it only one step further still.

If the E-series has one sonic disadvantage when compared to the the original GX1 it is that the digital oscillators lack a bit of real analog randomness and "raunch", especially since they provide no PWM (Pulse Width Modulation).

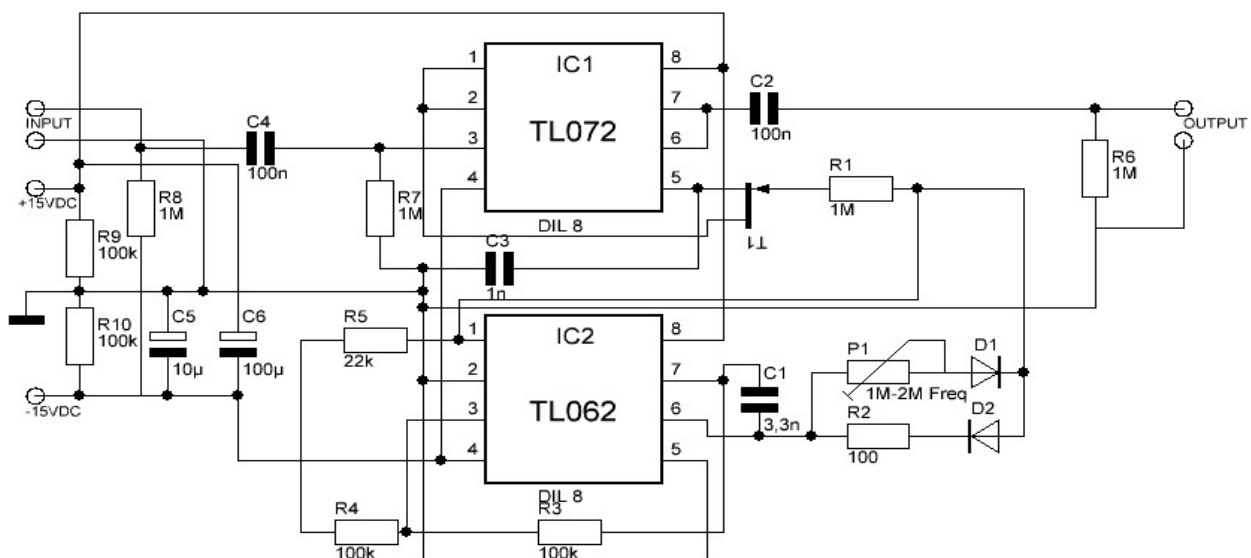
Furthermore: The GX1 sports a ring modulator on the mono synth (another true CS-series strength). I thus felt the need to add something similar anyway.

I did however not totally go down the same path but decided on a so called analog "bit"-crusher in stead, which is a "bit" of a misnomer because it is actually based on analog chips, so no bits to be crashed are in sight / audio range. Let's therefore call it an audio crusher from now on.

The idea to go this specific route actually came from the fact that I noticed during watching many a YouTube video that average and / or overly perfect sounding keyboards can become a lot more interesting by being recorded on cellphones. The occurring artifacts from low sampling rates and data compression are somewhat comparable to how early 8 bit samplers added character while later 16 bits incarnations didn't. 16 bits are certainly more perfect but 8 bits give the sound a certain attractive grainyness. It's also comparable to how the growl of an overdriven Hammond tonewheel organ is more popular then its pure sound.

The type of audio crusher I used does not provide real ring modulation between 2 signals but gates the audio signal, thus silencing it for very short intervals. At medium settings the results however become quite comparable to what we expect from a ring modulator. Another advantage of this solution is that the turning of a single pot actually provides a lot of different effects, from subtle, narrow band harmonic coloring through the already mentioned ring mod type effects to extreme sonic mangling.

OK, nobody actually talked about crushing audio at the time. Designers where still looking for the best possible sound in stead of ways to mess stuff up, so this is a bit of an conceptual anachronism but at least the solution is based on period technology. Assuming they would have seen any merit in it at all the Yamaha engineers could, theoretically, have developed something similar themselves.



Resistors:  
R1, R6, R7, R8: 1M  
R3, R4, R9, R10: 100k  
R5: 22k  
R2: 100  
P1: 1M/2M

Capacitors:  
C6: 100μ  
C5: 10μ  
C2, C4: 100n  
C1: 3n3  
C3: 1n

Semi-Conductors:  
IC1, IC2: TL072 and TL062  
T1: J201 or 2N5457  
D1, D2: 1N914

Fig. 9: This is the final audio crusher diagram Raphael produced. It shows the circuit that we actually built so if you follow this example your audio crushers should actually function from the word go.

Not bothering with printing specific circuit boards I salvaged pieces of empty board from the same D&R 1500 audio mixer that already provided most of the pots and switches for this project and used these as a sort of non-pre-drilled (ugh?!) breadboards for constructing 3 crushers.

This might all sound / read a bit improvised on paper but as Fig. 10 shows it has actually been executed reasonably graceful. Of course printed circuit boards are the accepted solution and more elegant anyway but technically a circuit board is nothing more then what the name implies: A non-conductive board on which a circuit has been built up out of discrete components. Strictly speaking using printed leads is only really a series production necessity. For a single "product" the more prototype oriented solution of working with connecting wires is just as viable. We're not talking micro-electronics here after all

If you do however still want printed circuit boards nothing is keeping you from it. Lately these can even be ordered from the Internet (see paragraph 21).

For practical reasons explained in paragraph 16 the audio crushers where positioned in the programmer box. Luckily enough I had built mine extra big in the first place!

They could be fed by a separate 9V battery but for obvious reasons I decided to use an on board 10V feed from SGX.

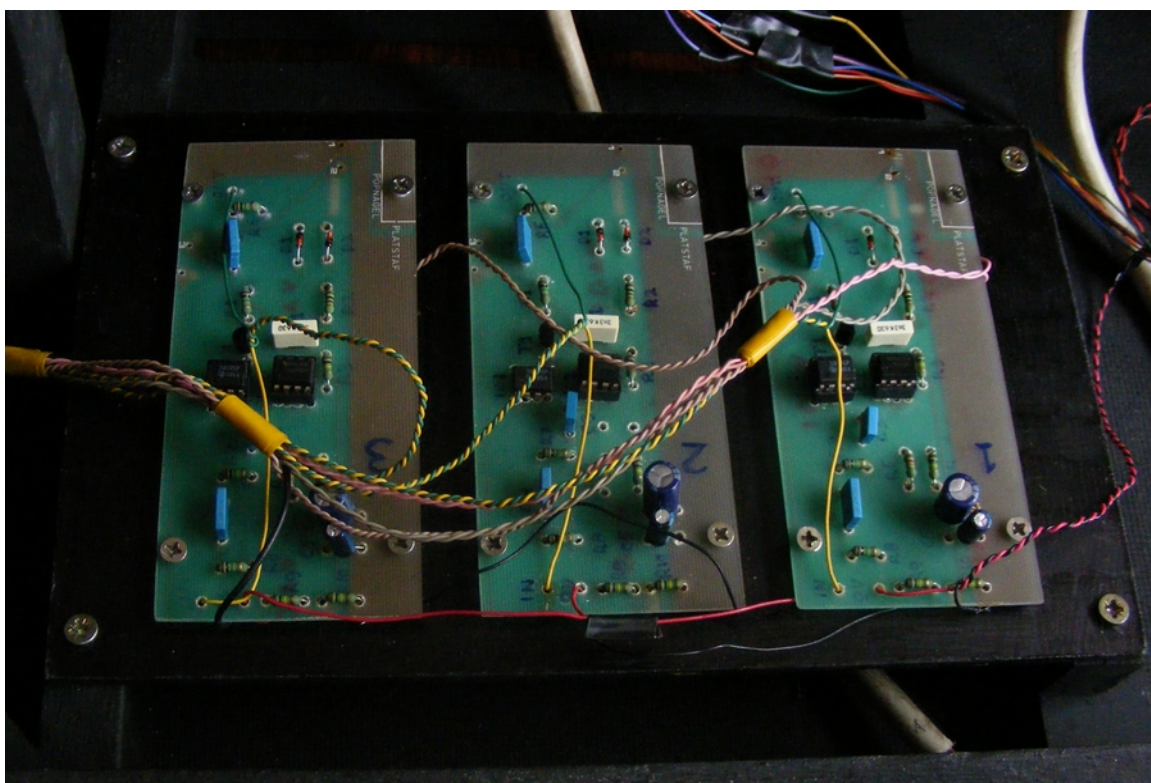


Fig. 10: The 3 audio crushers as installed in the programmer box

**A warning:** There actually was a problem with building these crushers that bugged me and my son Raphael for quite a long time. The original Internet design claims that 2 Texas Instruments TL 072 chips should be used. Do not try this because the circuit will then do nothing audible with the signal. You will instead have to use 2 similar but not entirely the same chips. In the end we used a TL 072CP for the actual audio preamp circuit (IC1) and a TL 062CP to produce the gating frequency (IC2) (see Fig. 9).

## 16 Splitting it up

I redesigned the output panel at the far right side of the programmer box to provide 3 outputs per instrument:

1. solo (poly)flute and (mono)orchestra total mix
2. solo (poly)flute and (mono)orchestra main channel (= total mix minus sections routed to the rotary channel)
3. solo (poly)flute and (mono)orchestra rotary channel



4. upper/lower/pedal drums, flute and orchestra total mix
5. upper/lower/pedal drums, flute and orchestra main channel (= total mix minus sections routed to the rotary channel)
6. upper/lower/pedal flute and orchestra rotary channel

This does still not provide a full output per individual flute and orchestra section plus individual drum output (as contemplated in the first customization guide) but that would already lead to 9 individual outputs without any direct or rotary channel routing. Feel free to do so on your very own version but for most needs this solution is already rather practical.

The far right panel (see fig. 11) contains the 6 outputs but also the in- and outputs for the 3 audio crushers described in paragraph 15. This made me decide to actually build the latter into the programmer case. Only a 10V feed was then still needed.

The crushers all have their individual input, control pot and output so through modular chord patching 3 of the 6 outputs can actually be processed independently. For instance: By processing the main channel but not processing the total mix channel one can create processed and unprocessed versions of the same sounds on different channels.

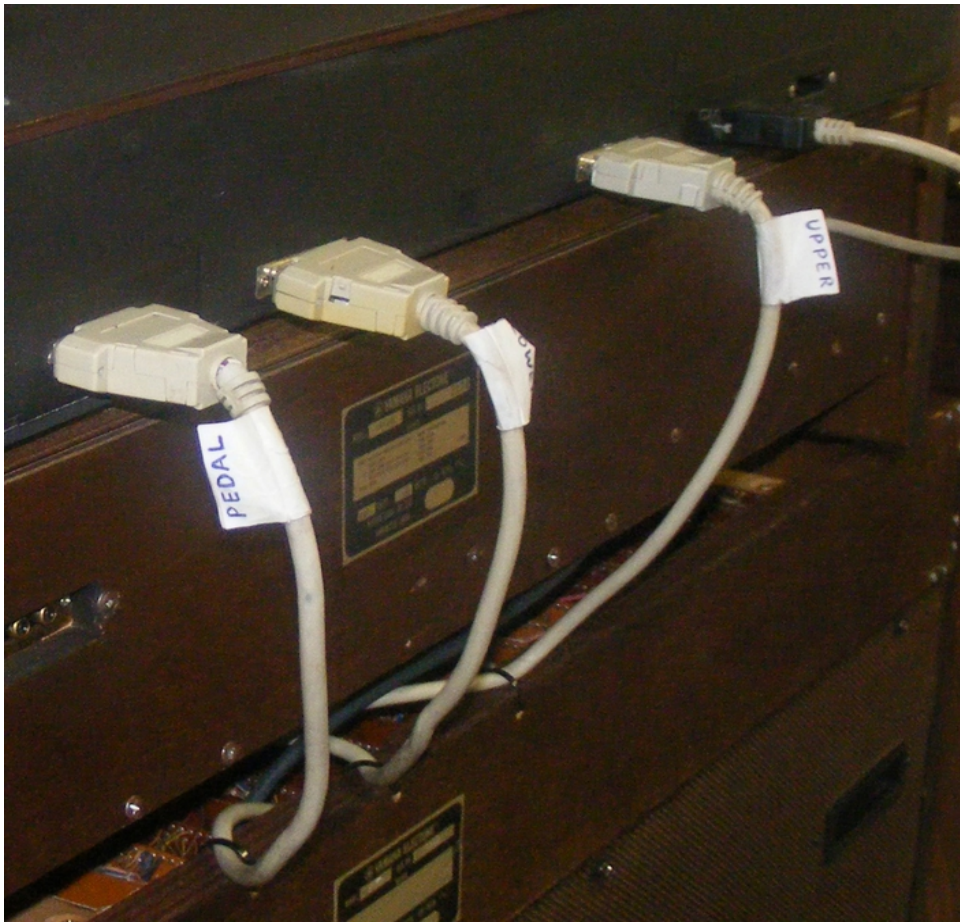
I will not describe all possible permutations here but one might agree that this is still a rather flexible system, again based on period technology. The only real disadvantage is that the bass pedals and drums cannot be isolated from each other.



**Fig. 11: The far right panel on the programmer box contains the individual outputs and the in and outs plus control pots of the 3 audio crushers.**

I extracted the main and rotary signals for this output section from the Leslie style connectors on the backside of both instruments. This, together with the 4 multipin connectors for the programmable sections, enables total detachment of the programmer box from the rest of the setup. Believe me: You wouldn't want to move the whole contraption in one piece (also see paragraph 6).

Since I could not find the right male connectors at the time I also built these from scratch. Because of tight tolerances this is quite a job in itself and therefore not for the fainthearted. So be warned!



**Fig. 12:** This picture shows that the original programmer box has been widened and now sports a 4<sup>th</sup> multi-pin input for the solo synth functions (the black connector to the far right). Also note the outputs on the back of the CSY 0.5 plus the E70's repositioned backside closing beam and trimmed back panel.

## 17 Detailing

A few small things still remained to be done:

- I decided to reinstall the lighting in the original E70 cover in the edges of the aforementioned remaining outer cover sections (see paragraph 11). One can just about see it under the daylight conditions in Fig. 1 but with dampened light it looks very smart.
- I also placed on of these lights above the volume pedals, something which, to my knowledge, not even a GX1 provides.
- The color of the various outer wood surfaces was matched.
- The repositioned controllers where neatly relabeled

I will not describe all these steps in detail. You will also not find templates for my panel layouts. It's much better to be creative yourself.

If you demands are purely functional there is no need for flashy stuff but the eye is of course also playing a role. I personally like the total to exhume a sort of natural integration that could be mistaken for an actual period Yamaha design. Fig. 1 speak for itself in that respect. It shows a classic organ setup, perfect for inclusion in your living room, mad professor's laboratory or count Dracula castle.

One could however just as well fit an EX1 with an equally wide programmer box replacing the original perspex music stand. Using the actual stand would also be a nice option, providing a direct look at all the wiring behind the transparent plastic, maybe even including some off the wall additional lighting. The overall effect would be much more future-retro while added light-organ functions could even take it over the totally tasteless disco-top. Perspex is however notoriously difficult to drill and cut so using the actual original EX1 stand might not be a good idea.

## 18 Comparing the SGX V2 to the GX1

The SGX has now been expanded into an instrument that is very similar to the original GX1. The CSY 0.5 adds a very expressive layer to the SGX's ability, especially when one considers the analog solo synth's aftertouch options and the extra organ section (see paragraph 2).

Although the whole setup might still not be the ultimate tool for experimental sounds it is very strong on parameter control. It for instance fits well into the good Yamaha CS tradition of providing individual LFO's for many functions.

Of course the GSX V2 can never fully replace the GX1. It would be a bit like claiming that you have built a brand new Stradivari out of old junk and in your own garden shed. The GX1 was there first. It will, among other things, always be remembered as the first fully programmable polysynth on the market and has been used by a few very well known artists. Collectors will therefore be willing to pay the price card that belongs to such a status.

On the other hand speculation often drives the originals out of the hands of those who actually know to use them best (How many top of the line violin players still own the Stradivari's they play?). In that respect it is nice to more or less do the Robin Hood thing and make the heritage available again for normal money, providing one is prepared to go through the whole customization process, that is (Let's be honest: In real life only a few things are totally free).

One could however also compare both instruments in somewhat more objective terms. How far have I come in creating something comparable to the GX1's concept and capabilities? Well, I think that I can by now claim that I have built an instrument which in certain respects even outperforms the original.

Fully describing both here would go a bit far but let's have a look at the most important differences.

Where the SGX V2 wins:

- A complete synthesis programmer per section. Of course you could theoretically insert one of those stand alone original programmers per separate GX1 section but they are even rarer than the instrument itself and could thus just as well have been made out of Unobtainium.
- Except the analog solo synthesizer all sections use digital oscillators. Following general lore many will actually see this as an disadvantage but at least these oscillators are always in tune. The GX1 was very difficult to keep in tune (as was the CS80 for that matter). For those still complaining: The SGX V2's monosynth is fully analog.
- The technology is also very dependable and stable in nearly every other aspect, especially when considering that it is more than 40 years old. The GX1 was however already notoriously instable and fragile when new.
- When the digital oscillators are driven hard (in other words: when the filters are opened wide) the sound becomes ever more digital and thus more modern. This provides a best of both worlds with timbres ranging from (virtual) analog to those reminding one of a PPG Wave without wavetable scanning or an Elka Syntex (see the links to audio examples in paragraph 21).
- Although the layers which make up a GX1 tone can be detuned to each other the SGX has a Celeste slider per section, adding an independent 2 oscillator detuning effect to all individual sections / layers, so even to the organ, chimes and vibraphone tones. One could claim that, when the upper and lower orchestra section are coupled and layered with the upper flute section, the combined sound is comparable to a 6 oscillator per key 7-voice polyphonic synth! Booah!
- The upper keyboard section has a speed adjustable repeat facility. With it every note is permanently retriggered as long as its key is held, constantly looping through both envelopes (except the release portion of course). This facility can thus be used as a sophisticated extra LFO. It also misses a modulation depth control but it is great for full depth string picking effects and modulation mayhem.
- The solo section does not only sport an aftertouch sensitive monophonic analog synthesizer but also a full (poly- / paraphonic) organ section with high harmonic frequency content tabs like 4" string and 8" oboe. The synth sound can thus be layered with an organ sound and slightly detuned to it. As already explained in paragraph 2 this is a great way to give "thin" single oscillator synthesizer sounds a boost and thus goes a far way in compensating the SGX's lower flexibility in waveform selection and mixing (Which is one of the GX1's strongest points).
- The solo keyboard is 3.5 octave long and the keys are full size instead of the 3 octaves with reduced key depth on the GX1 / EX1.
- Beside the EX1 none of the E-series models had a dedicated solo keyboard. To at least partly compensate for this the expression pedal can be tilted from left to right and vice versa for real time control of the filter cut off of the upper orchestra (synth) and flute (organ) sections. This gives these a lot of extra expressive power, which can also be used to further compensate the lack of



analog randomness.

- The, also original, E-series arpeggiator is a brilliant source for rhythmic effects and patterns. Especially the "free" mode, which remembers the exact trigger moment per note within a bar, is a long forgotten and underrated gem (Buzuki players unite!). The GX-1 does not have such a facility.
- It might not be very impressive when compared to more recent home entertainment technology but the SGX also has drum box synchronized, auto-accompaniment options on board. The GX1 also, more or less, has such a facility because the solo synth oscillator can be triggered by a drum sound but that's not the same as being able to generate complete polyphonic accompaniment patterns.
- The SGX has one extra volume / expression pedal for the solo section and thus 2 overall.
- Although one will have trouble thinking about the SGX V2 as a compact solution when standing beside it can be seen as such in comparison to a GX1, especially if one considers that a GX1 needs big speaker cabinets to actually produce an amplified sound. In such a configuration the floor space required for the GX1 will actually be nearly twice as large!
- It cost me as much to buy and rebuild the complete SGX V2, including the spare E70, as it would to buy a new but bland, low to middle class polysynth. A GX1 will, if traceable at all, cost you a fortune.

Where the GX1 still wins:

- The GX1 has much more facilities to shape and mix the oscillator waveforms. The SGX's P.A.S.S. sound engine does not provide adjustable pulse width, let alone PWM (Pulse Width Modulation). Beside sine, sawtooth and square an extra asymmetrical pulse wave is offered on the SGX but real continuous movement has to come from the adequate use of the (many) other facilities, such as the fully individually adjustable Celeste options per layer. Thus a fully analog, PWM-ing GX1 can sound like the walls of Jericho collapsing in perfect harmony. For analog purists this still is the only true way, however high the accompanying extra costs and complications might be. Personally I tend to be a bit more realistic and wish them all the luck they'll obviously need.
- On the GX1 user programmed sounds could be stored, assuming you had enough of those brilliant programmable matchbox cassettes. No such luck on a SGX.
- The upper and lower manuals and bass pedals on the GX1 are fully bi-timbral, meaning that 2 programmable synthesized sounds can be mixed per manual. The SGX also provides 2 mixable layers but here the 2nd layer is always provided by a flute section. This however is not as big a disadvantage as it might seem. Adding an organ sound still comes close to using the "add a sine tone after the filter" CS-trick described in paragraph 2. The upper flute section also provides chimes and vibraphone presets which are great for setting up Toto style "GS1 FM + CS80" layerings.
- On the GX1 both the solo and upper manual sections can generate portamento. On the SGX V2 only the analog solo synth generates portamento.
- The GX1 has a jummy Yamaha ring mod on the solo synth. The SGX has to do with "only" 3 analog audio crushers but they still come rather close and can be routed to ALL sections! (see paragraph 15).
- Yep, the SGX's solo keyboard is set much higher than the one on the GX1. In practice this is however much less awkward than one would expect.
- The GX1's solo synth has left to right key sensitivity, which is the best imaginable vibrato shaping control (Actually the whole keyboard lurches from left to right but on a monophonic instrument the effect is obviously the same). The CSY 0.5's solo synth however partly compensates for this by offering aftertouch controllable LFO depth.
- Theoretically the E70 actually has a similar vibrato control on the upper keyboard but this is no longer working on any of the E-series Yamaha's I ever tried (it depended on a special foam strip that deteriorates throughout the years). I've replaced it with a "wiggle bar" on top of the upper manual (see Fig. 1). One does however need an extra finger to operate this.
- The GX1's solo synth is also velocity sensitive, driving attack pitch swoop and attack time. Nice stuff, although in hindsight volume and filter cut off would probably have been even better. Again: The SGX's solo synth only has aftertouch. By the way: The EX1 does not have velocity sensitivity, nor aftertouch so in that respect a GSX V2 is actually superior to a similarly converted EX1!
- The GX1's solo synth has a ribbon controller. Not that I ever heard somebody doing anything worth while with it but still; knowing the CS80's excellent incarnation, I'd love to have one on board.
- On the GX1 individual drum sounds can trigger the solo synth. It was again hardly ever used by

- anyone but I'd still love to have it on board for more experimental stuff.
- The GX1 and EX1 have a special 11 pin split-out connector that makes all sections individually available. To the 3 original channels on the SGX V1 (mix, main and rotary) 3 extra channels for the CSY 0.5 solo section have now been added, making the total number of audio outputs only 6.

That is a lot to take in so let's formulate a more compact conclusion:

Both machines have their own strengths and weaknesses (the weight of which will mostly be influenced by personal preferences) but on average they are pretty much on a par. I for one think that having a complete programmer per section is a very big bonus but someone who looks at the whole thing from the original super-organ standpoint might hardly care.

So again: Of course a SGX will never have the reputation and thus desirability of it's legendary forebear. If you build an SGX V2 you will however own an instrument which is very comparable and even rarer.

**Not bad for a pile of little loved junk!**

## 19 Post Scriptum: Why didn't Yamaha build a true GX1 heir?

Well, they actually did. They developed a lot of new family members over the years, the CS80 probably being the ultimate analog synthesizer. It added a velocity and poly aftertouch sensitive keyboard to the mix and it's different oscillator design led to an even more personal character. OK it's not a true multitimbral instrument like the GX1 but when it comes to sheer musicality and expression few electronic instruments deliver the refinement of the CS80.

Then there were all the later Electone top of the line incarnations per generation. I already mentioned the EX1 and EX2. My SGX V2 is basically a conversion of the E70, the home-organ version of the EX2, with a CSY organ added to it, with full programmability added.

But why didn't Yamaha build a similar, fully programmable machine again?

Well, probably because the GX1 always was a bit of a mutation, being both a super-organ AND a super-synthesizer. As a development tool it made perfect sense but there is virtually no market for ultra-expensive instruments that can do both things equally well, so offering the ergonomics of the ultimate one-man live keyboard-instrument but also fully programmable in a similar hands on / one controller per function way. Even today!

In other words: Of course Yamaha could still have built an SGX equivalent themselves but imagine what it would have cost! And so they didn't.

But wait a minute! Basically they did!

Ever heard of the SK50D? It is an instrument from the early 80ties with separate monosynth, organ, poly/string and bass sections which are all fully programmable in a very similar, one hardware controller per function, way. The SK50D was however never to be famous (as was it's direct, CS80 descendant, sister the CS70M for that matter).

There were reasons for that:

- The SK50D's polysynth is paraphonic (In other words it only has one filter for all voices).
- Only the polysynth offers Celeste style detuning.
- None of the sections are bi-timbral in themselves.
- Each section has a lot less parameters to control.
- Worst of all: it's from the time when the Japanese did not yet understand that an instrument can sound too well behaved. There for instance is no possibility to generate Hammond style overdrive.

So although the SK50D must not be underestimated (it surely makes a beautiful racket when used effectively) it cannot really hold a candle to the GX1 or the SGX V2 when it comes to sonic character and versatility. I do however still think it is one of the sexiest looking keyboard-instruments ever. It's sleek wedge shape, containing 2 symmetrically stacked keyboards and a big control surface, bristling with graphically neatly matched controllers, is always a sheer delight to my eyes.

But I digress. Again!



Fig. 13: Music For Control(ler) Fetishists

## 20 Some closing remarks:

- The quality of a musical instrument is obviously not defined by the number of controls it offers. In fact the opposite could be claimed just as well since the more controls an instrument has the less intuitive it tends to be but lets be honest, a big part of the attractiveness of this instrument is its uncompromising wealth of direct access to every function. Not menu driven software solutions here. This is pure man-machine interfacing.  
When one adds up the total number of manuals (individual keys or pedals not counted), switches, pots, sliders, indicators and in- and outputs one gets to the following numbers:

E70 surface	191
E70 preset drawer	77
	+
standard E70 total	268
CSY 0.5	64
SGX programmer	89
	+
total	412

Only a rather big modular system will offer more controls. Therefore it is only fitting that the main power switch now carries the label: WORLD DOMINATION!

- By now my son Raphael has become a dependent help in repairing and customizing my synths. The poor fool has even, quite voluntary, decided to learn this stuff at school. For a father and son team we seem to be quite compatible (but maybe you should rather ask him). Without his reassuring presence I would for instance have thrown those darn audio crushers in the bin a long time ago. Being able to reflect on development problems has however proven to be a very wholesome thing. Thanks Raphael!
- An even older pall in this venture is Elie, know on the Organ Forum as Keyman2 (Yep, he's a rather private person so he does not want his family name to be mentioned here). Although he has not literally contributed to the redesigning and rebuilding processes he has been a constant inspiration and source of information throughout the years. So thank you as well, "Keyman2"!
- I have never actually seen a GX1, let alone played one. A direct A to B compassions has therefore yet to take place, although I have at least been able to try out an EX1 once. My knowledge about the GX1 is therefore totally second hand. I have been as precise as possible but do not be afraid to correct me if my sources where incomplete or I have misinterpreted anything. I also updated the first installment of this guide a few time so why not do the same to this second one?



## 21 For further listening / reading / viewing:

- Want to hear the darn thing?  
At the moment of writing I have not yet published music that was specifically performed on the SGX V2. The SGX V1 can however be listened to. A quite neat example is the track "Long Live Technology" from my "(Post)Modernisms" project, especially since the SGX performs almost all the parts on this track:

<http://www.brassee.com/electronicmusic.html#postmodernisms>

The clear Jean michel Jarre inspiration of "Long Live Technology" actually came from the fact that the SGX can sound rather like an Elka Syntex, so the reader can verify that bold claim as well (Also see paragraph 18).

- Throughout the rest of the (Post)Modernisms project a lot of other examples can be found, including some for the freed up CSY solo synth / organ combo, although in that case still in it's Polycheesy 800 form.
- Another nice source for a range of SGX V1 experiences is "Balance":

<http://www.brassee.com/electronicmusic.html#balance>

- And while I am at it: Just in case you found this article through a direct link I would also like to promote the rest of the content of my website:

[www.brassee.com](http://www.brassee.com)

- Maintenance tips for older instruments, specifically CS Yamaha's, can be found on the Old Crow's Synth Shop website:

<http://www.oldcrows.net/~oldcrow/synth/>

- The YouTube video that actually inspired me to use the analog audio crushers can be found here:

<https://www.youtube.com/watch?v=aVQM2DOn3Tc>

- You can find the original crusher design here:

<http://tagboardeffects.blogspot.nl/2012/10/analog-bit-crusher.html>

Do however heed the warning in paragraph 15.

- If you want to buy a prefab circuit board for your audio crusher you can order the Sonic Reducer:

[http://www.parasitstudio.se/store/p11/Sonic\\_Reducer\\_Bitcrusher\\_PCB.html](http://www.parasitstudio.se/store/p11/Sonic_Reducer_Bitcrusher_PCB.html)

I do however not have any personal experiences with it so do your own checking first.

- Although not always humming with busyness the "Unlocking the E70" thread on the organ forum is still going strong.

<http://www.organforum.com/forums/showthread.php?6788-Unlocking-the-Yamaha-E70&p=436054&posted=1#post436054>

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