9090 Construction and Operation Guide

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http://introspectiv.org/

Introduction

The 9090 is an analogue drum synthesiser project based upon the legendary TR909. It incorporates all drum circuits (bass and stare drums, tom drums, hand clap, rim shot, cymbals and hi hats) together with necessary noise and power supply circuits, and a MIDI interface implemented using a PIC microcontroller. The project is built across two 200mm by 160mm boards, designed to fit within a 2U height 19" rack enclosure.

The User Guide and other documentation

This isn't really a comprehensive user guide, in that I have only included details that I feel are of particular importance. Basics of electronic construction are not covered. If I have missed anything, please let me know and I shall try to add it. In fact all of the documents will be frequently updated including this one.

The following documents are available to assist you in the construction of your 9090. I recommend reading through the notes contained within this guide before commencing board assembly.

1. The *9090 parts list* provides a separate list of components for each circuit section. Also present is a capacitor and resistor substitution guide, which suggests alternatives if you experience difficulty in obtaining any of the uncommon capacitor values.

2. A *9090 wiring guide* illustrates how potentiometers are wired to the boards. It shows how to make connections between the two boards, wiring for MIDI jacks, AC input and so on.

3. The *9090 schematics* are invaluable for troubleshooting and making modifications. During construction you'll probably need to refer to the individual outputs section, as there are some components to mount directly to those sockets.

The parts list has been thoroughly checked for mistakes or omissions, but errors may still be present. Please e-mail me if you find any discrepancies. If you discover any inconsistencies between the schematics and parts list, then the schematic is most likely to be in error, not the parts list.

9090 Features

Some features of the 9090:

1. The versatile Bass Drum has several additional controls. **Pitch** sets the initial pitch. **Tune Decay** (formerly *Tune*) sets the speed at which the pitch is swept (lowered) as the drum sounds, and **Tune Depth** sets the sweep amount. Rotating the Tune Depth control clockwise produces a lowered final pitch. Manipulating the Pitch, Tune Decay, and Tune Depth settings can produce a bass drum ranging from relatively flat sounding, to a very energetic, punchy kick that really cuts through the mix.

2. A Bass Drum **Distortion** control causes an increasing clipping effect as it is rotated clockwise. This simple addition takes advantage of the diode clamp circuit that 'rounds off' the triangle wave from the VCO, by overdriving the diodes to produce a more square, overdriven sounding wave.

3. A **Tune** control has been added to the Hi-Hat voice. This affects both open and closed-hat sounds together. It works in the same way as the tune control for crash and ride cymbals.

4. The 9090 has a complete MIDI interface. Drum sounds are assigned to individual keys and are velocity sensitive. By means of the Configure button, MIDI channel or note assignment (how the drum sounds are assigned to various notes across the keyboard) can be altered using MIDI messages. The interface, located on Board 2, is implemented with a 4MHz PIC 16F84 microcontroller. A number of latches, a discrete 6-bit DAC and demultiplexers provide separate trigger and velocity signals for all drums. A MIDI Thru jack allows chaining of further MIDI instruments via the 9090.

5. Built-in MIDI to DIN Sync converter. The DIN Sync Out jack may be used to synchronise instruments with a 24PPQN DIN Sync input to MIDI clock, such as the TB-303, etc. Ensure that your MIDI sequencer is set to transmit MIDI clock information if you wish to use this feature. The converter does not provide a continue signal, so your sequencer should be set to always transmit a start command, never continue.

6. A useful MIDI LED provides visual indication of all MIDI data, with the exception of clock information.

7. Individual Outputs. Each drum circuit has an individual output jack. All drum sounds are routed through a Main Output, which is implemented by taking a switched return from each individual output jack and feeding it to the main amplifier. In the standard configuration, plugging a lead into an individual output socket removes that drum sound from the main output.

Components

Most of the resistors may be 1/4 watt, 5% carbon type. Some resistors need to be 1% metal film, specifically some used in the MIDI interface (velocity DAC circuit), Hi-Hat and Cymbal (DAC for sample data and envelope generation). I decided to use 1% resistors throughout on the prototype 9090 since they are relatively cheap anyway.

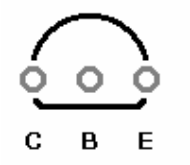
For front panel mounted potentiometers, the prototype uses the 16mm diameter carbon track RV160 series manufactured by Alpha. They are *not* mounted to the PCB but are wired via headers, so you are free to use whatever type you wish. All potentiometers are single, except for the dual-gang Master Volume control. Note that the convention used within the 9090 parts list is that ‘A’ represents logarithmic and ‘B’ represents linear.

The trim potentiometer used in the Hand Clap circuit is a 3/8” single turn cermet type. Manufacturers for this part include Bourns (3386P series), and Spectrol (63P series).

Electrolytic capacitors should be at least 25V, except where stated, and radial mounted. There are a small number of capacitors which need to be rated at 35V, particularly the high value capacitors in the power supply circuit. It is inadvisable to use an electrolytic capacitor having too higher voltage, because the capacitor will be physically larger than necessary. Space on the boards is rather tight.

Non-polarised capacitors can typically be polyester or polystyrene types, unless otherwise stated. Pitch spacing on the boards is 7.5mm for most non-polarised capacitors, with the exception of C147 and C148 which are 2.5mm pitch. These two capacitors are located near to the PIC.

The BC549 transistors can be pretty much any NPN transistor that corresponds to the same pin out. For example: BC550, BC548, BC547 etc. However, I recommend using BC549 or BC550 only as these are low noise devices. The transistors specified as BC559 can be any general purpose PNP types that have the same pin out. For example the BC560 may be used instead. The pin arrangement for the BC549 and BC559 is shown here, as viewed when looking at the top surface of the PCB, not the underside of the transistor itself.



PCB footprint for BC549, BC559 etc. transistors

The original snare drum circuit requires two 2SD1469 transistors. These parts are used in VCA arrangements which shape a filtered noise signal, creating the 'snappy' sound of the drum. They were most probably chosen for their low Vce(sat) characteristic, allowing for a greater attenuation range. A regular BC549 could be used in their place but the snappy will be quieter. Increasing some gain parameter elsewhere would compensate for this, but a side effect might be intrusive noise forever present on the snare drum output. Work is being done to determine an easily obtainable replacement for these. The PCB has a ‘spare’ collector pad for Q16 and Q20 and the pads are labelled, making it easier to fit different transistors.

The Crash, Ride and Hi-Hat each use a 27C256 EPROM which contains the sample data. If you chose to program your own EPROMs then virtually any standard 27C256 should do. Devices made by the likes of ST, AMD, and NEC have been used without problems. You could also use OTP (on-time programmable) PROMs. I advise against the use older 27256 devices since they can draw excessive current from the 5V supply, causing audible noise on the output (like a constant tone, or hum) as the sample data is clocked out.

A CA3080 type OTA is used for the VCA within the Hand Clap, in place of the original BA662.

The clock circuits in the crash, ride and hi-hat circuits each require a 4011 quad NAND IC, and this IC must be an *un-buffered* type for the oscillator to work correctly. That is, the part number must contain **4011U**. Typical part numbers may therefore be 4011UB, 4011UBE and so on. A buffered type i.e. 4011B, etc. is *not* suitable. Some people have expressed difficulty in obtaining these versions of the 4011 but they are certainly still available. In the UK suppliers like Maplin, Rapid and Farnell stock them.

Various PCB assembly notes

A number of resistors and capacitors need to be mounted directly to the individual output sockets, together with a common ground and mix left / right connection. Assembling this part can take some patience. Alternatively a small jack PCB could be made, or use a section of veroboard. The sockets and associated components were built onto a small home-made PCB for the prototype 9090. This PCB was kindly supplied by Mark Smith whom I understand would be willing to sell a similar PCB to anyone interested.

All wiring to the boards can be made through 0.1” headers (0.256” for power connections). Use of headers for all wiring does add to the expense slightly, but the ability to quickly disconnect all wiring from the boards makes servicing the 9090 so much easier. Similarly it is recommended that all ICs are mounted in sockets. I acknowledge the arguments against this practice, but de-soldering an IC from a double-layer board does take a degree of skill. At the very least the PIC and EPROMs should have sockets.

Heat-shrink tubing comes in very useful. Shrink tubing adds mechanical strength and a professional look wherever a wire connection is made to a solder tag, such as with potentiometers, sockets and so on. If applicable, use some larger tubing to insulate wiring to the transformer and other internal mains wiring.

Enclosure design

The prototype 9090 was built into a 2U height 19” rack enclosure which was obtained from Maplin Electronics here in the UK.

The front and rear panels were made by Schaeffer in Germany.

There aren’t really any specific rules as to how the various potentiometers and LEDs should be arranged on the front panel of your 9090. However, a front panel layout scheme similar to that on the prototype unit is recommended in order to keep wiring short.

If you wish to use a different kind of enclosure for the 9090, such as a desktop box, then it may be necessary to connect potentiometers to the PCBs using longer wires. Proceed with caution when doing this as relatively long wires can result in unwanted interference and noise. The use of screened wire might be necessary in some situations.

Power Supplies

Important: It is entirely your own responsibility how you power your unit. I will take absolutely no responsibility for your actions with the *9090* boards. You are responsible for your own safety. The advice on mains transformers is given only for those who know how to wire mains rated equipment safely. If you do not know how to do this then make no attempt to do so. Similarly you must exercise extreme care when using an AC adapter, ensuring that it is operated within specification.

AC input socket, J8

This is the socket on Board 1 where an AC input is made. Pins 2 and 3 are 0V, and the outer pins are 15V AC connections to the bridge rectifier. It may be a good idea to ‘key’ the AC connector by removing pin 3 of header J8, and inserting a small amount of epoxy glue into pin 3 of the matching AC plug housing. This way, it will be almost impossible to mistakenly fit the AC connector into either of the DC power headers, which would have catastrophic results.

AC mains adapter

The safest method of supplying power to the 9090 would be to purchase a self-contained AC adapter, of the type built into an external plastic enclosure, often forming the plug itself. This way there is no risk (nor necessity) to come into contact with hazardous mains voltages. The standard 9090 will draw approximately 440mA from a single, 2-wire 15V AC input, so ensure that the adapter is definitely capable of constantly supplying *at least* **500mA at 15 Volts AC.** You *cannot* use an adapter that has a DC output. It *must* have AC out. I would prefer to overrate the adapter, so if you can get something nearer to 1 amp, then it would be better.

The standard method of connecting a mains adapter to the 9090 would be using a low voltage barrel-type connector, often referred to as 'DC power' connectors. They are available in a small number of sizes; 2.1 or 2.5mm internal pin diameter connectors would be ideal here. Your AC adapter may already have a suitable plug attached, so you will require a matching socket for that. The socket is then wired to pins 2 and 4 on connector J8. If your socket has a metal body mounted against a metal chassis, then it is essential that J8, pin 2 (0V) is connected to the outer shroud (outer contact) of the socket. Otherwise excessive hum or even damage could result.

I personally have not tried an external AC adapter with the 9090. You are entirely responsible for your own safety and for ensuring that a suitable power supply is used. It may take a bit of searching to find a suitable AC adapter. Please let me know if you find a good source a suitable self-contained PSU for the 9090.

Internal mains transformer

If you chose to use a mains transformer, then it should have a centre-tapped, or twin secondary. With the centre tap, or common, of the secondary connected to J8 pin 2, the secondary winding end wires are connected to J8 pins 1 and 4. In this configuration each side will draw approximately 200mA. For various reasons I suggest overrating by a factor of about 2, so a transformer of rating **15V – 0 – 15V @ 500mA**, or **15 – 0, 15 – 0 @ 15VA total** should be used at minimum.

Heatsinks

Heatsinks should be used with the two 15V regulators. Whether or not they are actually needed depends upon the AC supply used, local temperature, additional circuitry you connect to the 9090's power supply, and so on. It is worth considering that the unit may be used in extreme temperatures (situated near a spot light, for example). Unexpectedly high output from a transformer due to loading conditions or mains supply variations can present an excess voltage drop across each regulator. Heatsinks are cheap, so it is very worthwhile including them. The use of thermal pads gives electrical isolation, which is essential advisory if your heatsinks are in contact with the chassis or each other. In the prototype 9090 the 7815 and 7915 regulators were *very* hot to touch and therefore heatsinks were fitted to those. The 7805, however, runs relatively cool.

Configuring the 9090

There is no need to perform configuration when the 9090 is first built and tested. The new pre-programmed PIC microprocessor will already contain the default values, and it will not be necessary to re-configure it in order to troubleshoot a new 9090. Hence, it is not advisable to attempt any of the following procedures until the instrument has been successfully tested. In fact, when you turn on your 9090 for the first time ever you may notice the MIDI LED flash several times. This is the PIC initialising itself with default values.

By default, assignment of individual drum voices to note numbers follows the General MIDI Percussion Key Map. The 9090 will respond to data sent on a specific MIDI channel only, and the default setting for this is channel 10.

The MIDI receive channel may be changed. Mapping of drum voices to note numbers may be reprogrammed also, to suit your requirements.

Exercise caution when reprogramming key assignments for drum voices, because it is possible to completely change how the drums are mapped across the keyboard – or even disable any or all sounds. It *is* possible to disable the 9090 in some way through bad configuration. It is advisable to keep a 'default values' Sys-Ex file should the need for it arise.

The Configure Button

Configuration mode is invoked by pressing and holding the Configure Button while switching on power to the 9090. Try to ensure that no MIDI data is inadvertently transmitted to the 9090 (other than MIDI clock) while doing this. The MIDI activity LED will flash rapidly, indicating that the instrument is awaiting data. At this point it is possible to change the MIDI channel on which the 9090 operates, or reprogram drum assignments to keys.

To set the MIDI receive channel

Receive channel selection is achieved by sending a single note-on message to the 9090 while it is in configuration mode. Set your sequencer (or keyboard), connected to the 9090's MIDI-in port, to transmit note information on the desired MIDI operating channel for the 9090.

- Ensure the Configure Button is held while switching on the 9090. The MIDI LED should flash at a steady rate.

- Play a single note from your sequencer or keyboard.

The 9090 will be assigned to the MIDI channel contained within the first note-on message it receives. The MIDI LED should briefly flash in a distinct manner to confirm the procedure has been successful. The 9090 will then revert to normal operation.

The PIC is supplied with the MIDI channel pre set to 10.

To reprogram drum assignments to keys

Assignment of drum sounds to individual keys across the keyboard may be altered using a MIDI System Exclusive message, generated using the Sys-Ex editor within your sequencer. The general structure of this message is shown in the table below. It is always 27 bytes in length. When the PIC is first supplied, the note assignments for each drum are as those shown in the third column.

Byte #	Function	Default (hex)
0	Sys-Ex Start	**F0**
1	Identifier	**00**
2	Identifier	**90**
3	Identifier	**90**
4	Bass Drum	23
5	Bass Drum	24
6	Rim Shot	25
7	Snare Drum	26
8	Snare Drum	28
9	Hand Clap	27
10	Hand Clap	27
11	Low Tom	29
12	Low Tom	2B
13	Closed Hat	2A
14	Closed Hat	2C
15	Mid Tom	2D
16	Mid Tom	2F
17	Open Hat	2E
18	Open Hat	2E
19	Hi Tom	30
20	Hi Tom	32
21	Crash Cymbal	31
22	Crash Cymbal	31
23	Ride Cymbal	33
24	Ride Cymbal	33
25	Cymbal & Hi-Hat Sustain	00
26	Sys-Ex Finish	**F7**

Those entries in **bold** should not be changed. Most of the remaining hexadecimal values denote which key the corresponding drum is assigned to. Individual notes across the entire keyboard range are represented by the values 00h to 7Fh, although 00 is reserved. With the exception of the rim-shot, each drum sound can be assigned to two different keys. To assign a drum to one key only, specify that key value twice. To disable a drum completely, assign it to key 00h in every case.

The Cymbal & Hi-Hat Sustain byte selects whether cymbal and hi-hat sound playback ceases when the appropriate note-off message is received. The default value of 00h causes these sounds to silence immediately if the key is released quickly. Changing this byte to 7Fh causes these sounds to sustain fully at all times.

The data within your sequencer's System Exclusive editor may look something like this:

```
F0  00  90  90  23  24  25  26  28  27  27  29  2B  2A
2C  2D  2F  2E  2E  30  32  31  31  33  33  00  F7
```

The procedure for transmitting the System Exclusive message is as follows:

- Ensure the Configure Button is held while switching on the 9090. The MIDI LED should flash at a steady rate.
- From your sequencer, send the System Exclusive message once.

The MIDI LED should briefly flash in a distinct manner to confirm the procedure has been successful. The 9090 will then revert to normal operation.

Mailing list for *introspective.org*

There is now a mailing list for introspectiv.org where you can meet and discuss technical issues with other people working on the 9090 project.

The group homepage is http://uk.groups.yahoo.com/group/introspectiv.

Outro

This document is a 'live' one to which I shall occasionally add to. Please contact me if you would like to see something added or clarified. Tell me whether or not this document has been particularly useful to you.

Thank you for purchasing the 9090 boards. I hope this project is an enjoyable one for all whom are brave enough to attempt it.

Special thanks, in no particular order, to: Tony Allgood, Colin Fraser, Mark Smith, Schaeffer, those nice people on the Synth DIY list, my girlfriend Lucy for not having left me yet and me for all my hard work.

Trevor Page, November 2002.

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