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Other booklets

Schematic to Reality – an excellent primer that should help you get over your initial bafflement. Also includes an appendix of some great circuits.

Handmade Electronic Music – Nicolas Collins' book – the audio hacker's bible.

Rich Decibels

Rich is an electronics engineer that reclaimed his soul from the corporate world and is devoting it instead to the pursuit of weird noises. Now that he has a bit of a clue he's started teaching other weirdos how to make weird noises too. If you're interested in learning about this stuff email richdecibels@gmail.com once you're back in the real world and he'll let you know about upcoming workshops.

Mind Kits

Mindkits.co.nz is a small company that is trying to spread the love of electronics by sourcing parts and kits that have previously been unavailable in NZ, and combining them with good tutorials online. They hooked up this workshop with about a 70% discount on all these parts.

About This Workshop

Have a flick through some booklets, plug some circuits together, twiddle some knobs, and ask lots of questions. You probably won't break anything so just play around and see what happens.

Getting Started in Audio Electronics

Electronics is actually pretty easy to get into because there's heaps of info online and the parts are cheap. Like any new skill you just have to start simple and gradually build on your knowledge. Work through some simple projects and ask lots of questions! There are instructions for projects of all different difficulty levels available - if you've never done anything like this before just start with the simple ones and work up to the more complex stuff. Just making your very first beeeeeeep is a very satisfying experience. Here are some places to start:

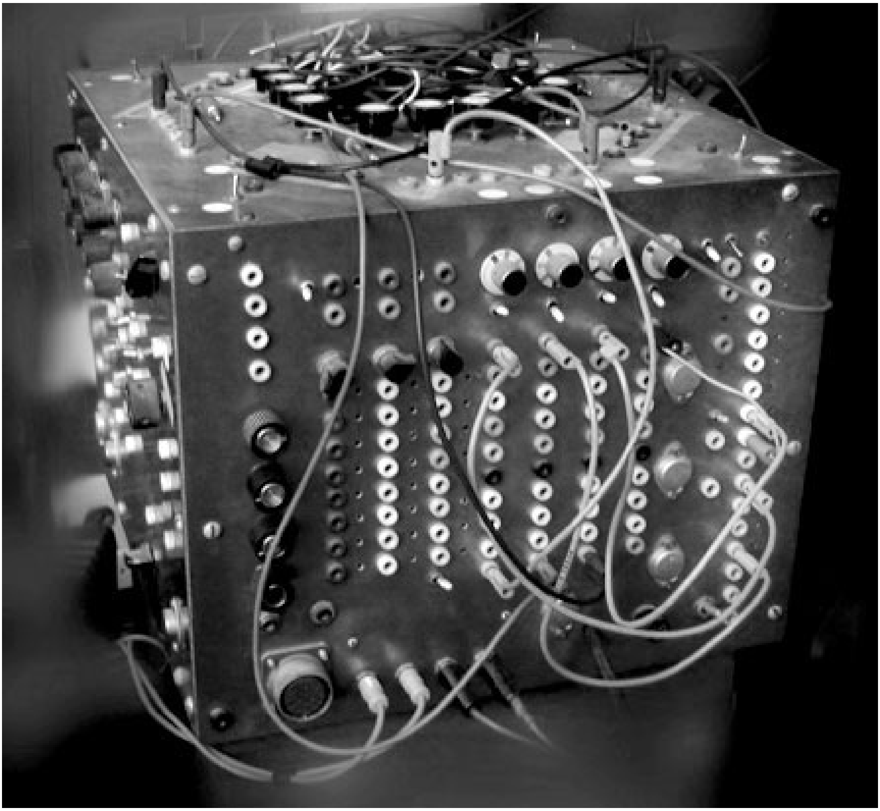
Electronoize Playshop

A nice feller by the name of Bbob Drake runs a workshop called Electronoize Playshop in Ohio. He has shared his tutorials and circuits online. I've printed up some of his stuff here on page 7 - it's the perfect place to get started.

Beavis Audio Research

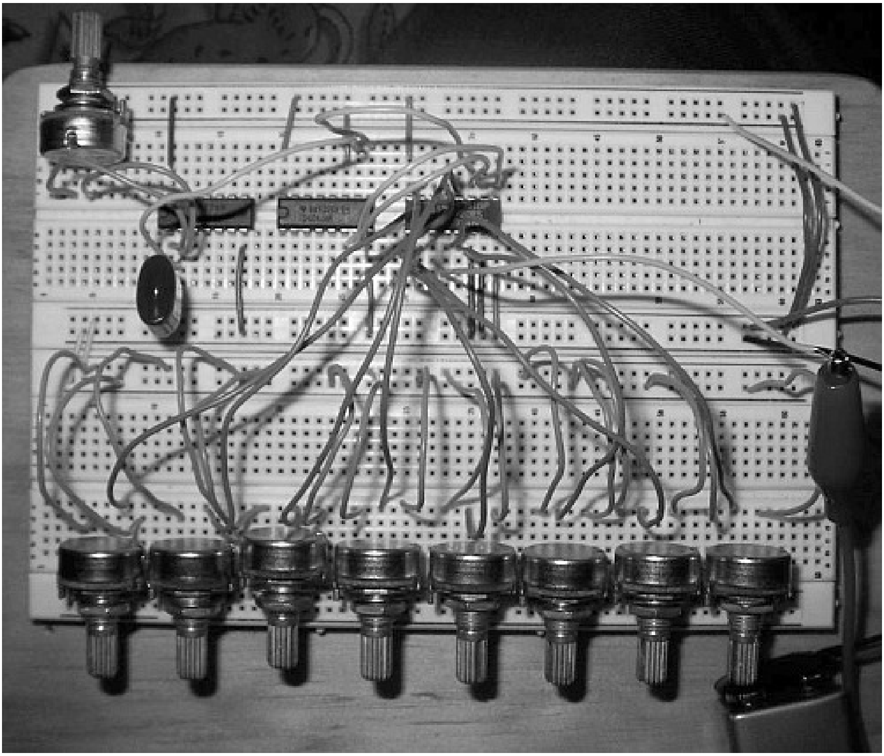
Dano at Beavis Audio Research is a complete guru. His website is a massive resource of great circuits and articles, all pedantically well documented and explained for the absolute beginner. He leans towards guitar stuff but he also covers a lot of really useful basics. He is the author of the *Schematic to Reality* booklet, an excellent introductory article to help you decipher the thousands of alchemic symbols you're supposed to understand. I have collected a couple of his circuit designs in that booklet too; just a tiny fraction of what he has to offer.

Electro-music Lunetta Forum



Electro-music.com is a massive community of musos, geeks, and weirdos with a really broad spread of interests in the realms of audio hardware, software, instruments, synth building, music... you name it. One specific sub-forum of interest is the lunetta forum, a small group of really active and astoundingly helpful characters that are happy to help out the most ignorant of newcomers. *Lunetta* is an informal name given to the lofi logic synths that are featured heavily in this document, named after performance artist and audio pioneer Stanley Lunetta. Some circuits that have been developed by this community are included here (page 28).

Milk Crate



Milk Crate is a group in Aussie that uses nonmusical means to make and record music in 24 hour bursts. One of the conveners Sebastian Tomczak has produced some really slick circuits and documented them in a little series called *fun with sea moss*, some of which are reproduced here on page 32.

Handmade Electronic Music

Nicolas Collins is generally considered to be a bit of a hero in the DIY audio hardware community for writing *Handmade Electronic Music* - the only book you'll ever need to read on the subject. It would take most of a lifetime to work through all the excellent circuits and ideas and it's targeted at people with zero electronics experience, e.g. "moisten your fingertip and prod around the insides of a battery operated radio." There are a couple copies of the book floating around the workshop. Or can get a copy from ziwi.co.nz for $60 delivered and it comes with a sweet DVD. There's also a copy at Wellington Central Library.

Electronoize Playshop

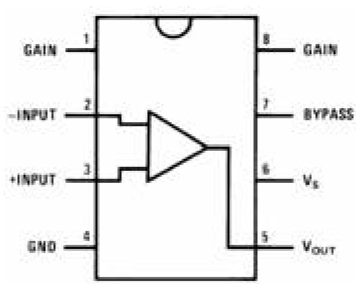
fluxmonkey.com/electronoize

ICs

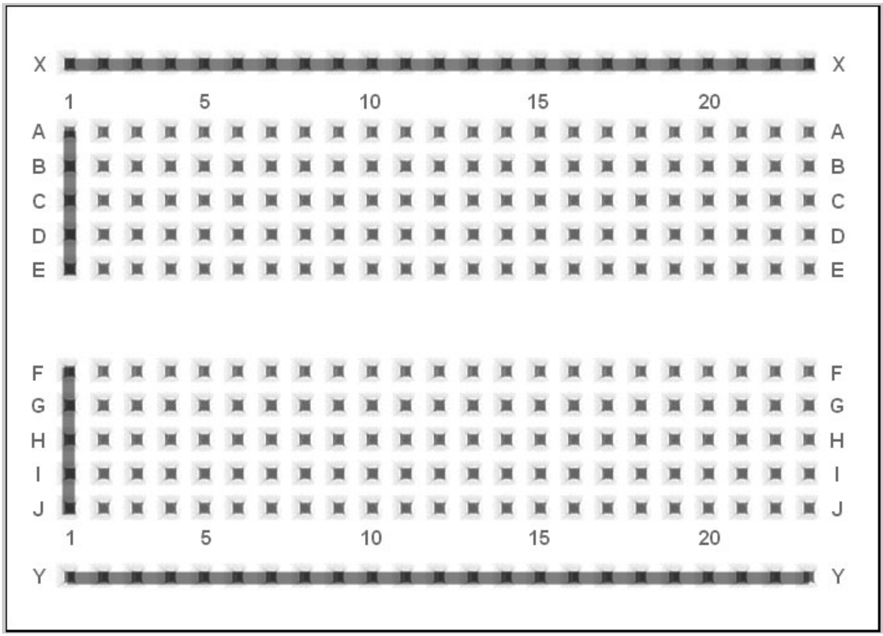
Integrated circuits are just little building blocks that have more complex circuitry inside them. The ones we'll be using come in small rectangular packages with 8, 14, or 16 leads. This package is called a "DIP", meaning dual inline pins. The LM386 has 8 pins:

IC pins are numbered in order, counter-clockwise from the little dot in one corner. Occasionally the dot is missing, in which case the little half-moon notch will indicate which end is "up".

The line diagram shows how the inner circuit is arranged (different for various ICs). The labels give information about the pins In this case, "Vs" on pin 6 indicates the power supply (Voltage) connection; pin 4 is ground.



How breadboards work



Breadboards have holes connected together in patterns; you stick components in the holes to connect them together

Each set of 5 vertical holes are connected together; so if you stick one lead in hole “A1”, and another in “E1”, they’re connected.

The channel in the middle is not connected; so “E1” and “F1” are not connected together. That channel is the same width as most integrated circuits, so we’ll usually place ICs straddling that channel so you can make separate connections to each side.

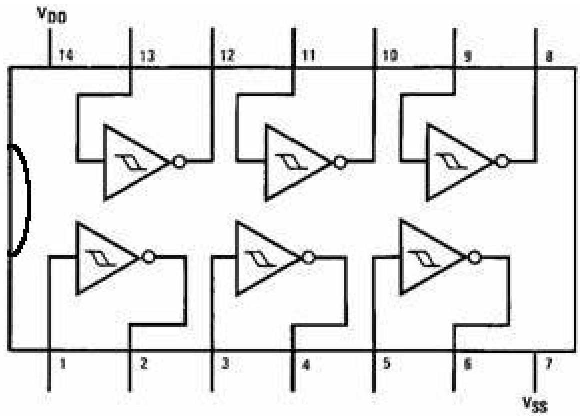
The outside horizontal “buss” lines are also connected together; a lot of times, you’ll use one of those lines for power and the other for ground. Some breadboards have 2 busses on each side, which can be handy--just remember which one is ground and which is power.

40106 Oscillator(s)

This week we're building our first oscillators, hot damn. Oscillators produce AC signals, which we can amplify and hear as tones. Oscillators can also control other oscillators, making more complex tones. We'll do both of those things, then we'll put them in fancy spray-painted boxes, sell them to suckers on e-bay, and retire to Vermillion. Hot damn.

The basic oscillator building block we'll start with is based on the 40106 integrated circuit. The 40106 has 6 different digital circuitry blocks, called "Schmitt Triggers" or inverters. Each inverter can be turned into its own oscillator just by adding a resistor and capacitor. So you can get 6 oscillators out of one chip.

Here's a picture of the 40106, showing the pin numbers and the 6 inverters:

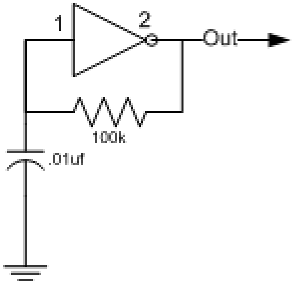


BTW, most chips do different things and have different pin-outs. You can always download the data sheet for a chip to get this info (google for "data sheet" and the chip number). Data sheets also often have sample schematics that can help get you started using a new chip.

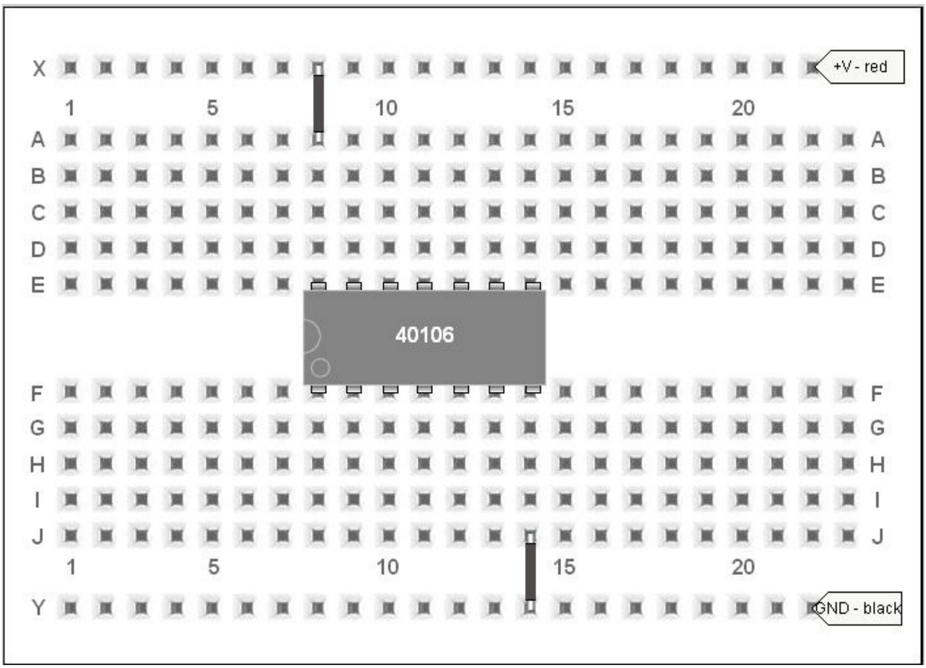
In this case, VDO (pin 14) is the positive power connection, VSS (pin 7) is the negative or ground. These connections are not always shown on schematics you find on the internet, they're just assumed. Schematics also just take a shortcut and show the circuit elements that are being used (they don't show the whole chip); in this case, each of the triangle thingies w/ the circle on the tip is an inverter. Sometimes they won't even tell you what pins to use--check the data sheet if you ever need to know which pins are which, or where the power goes. On chips like this with multiple elements, all the inverters on the chip are the same, so you can pick whichever one makes the layout easiest.

Oscillator 1

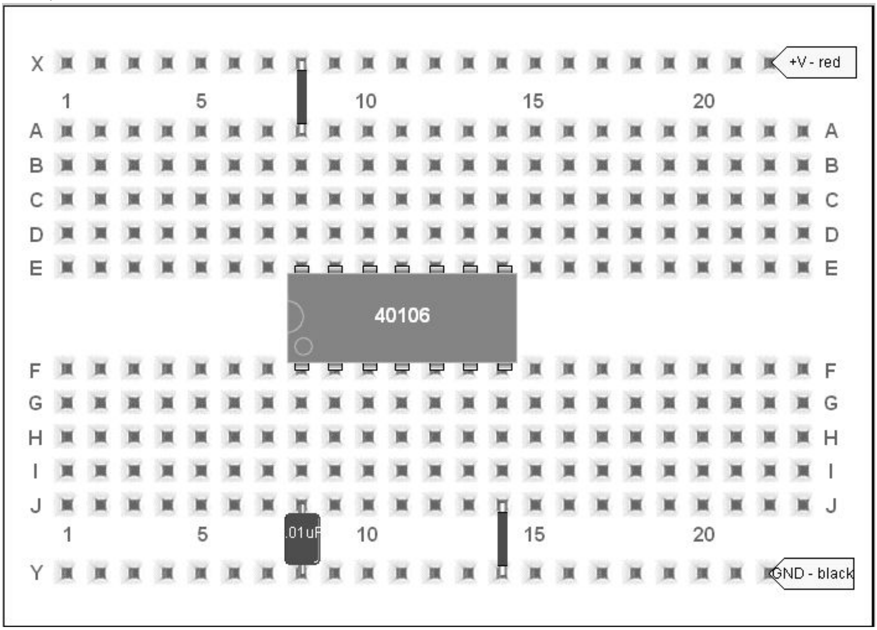
So that's the IC, here's the schematic for our basic oscillator, using 1 inverter, 1 resistor, & 1 capacitor:



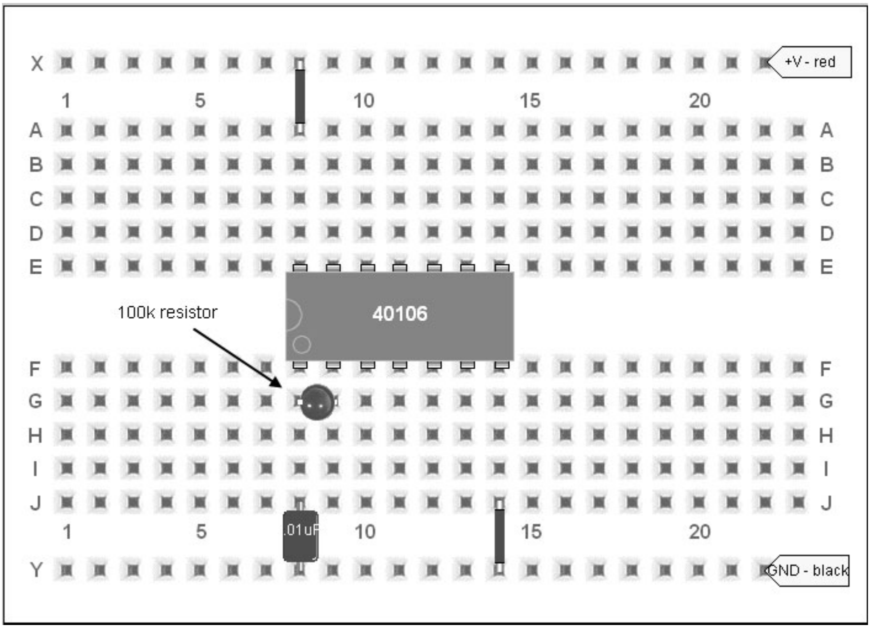
This is one of those schematics that omits the power connections, and just shows the basic circuit building blocks (although it does show the pin numbers). Here's how to breadboard it… first place the chip, wherever you have room, and add the (assumed) power lines:



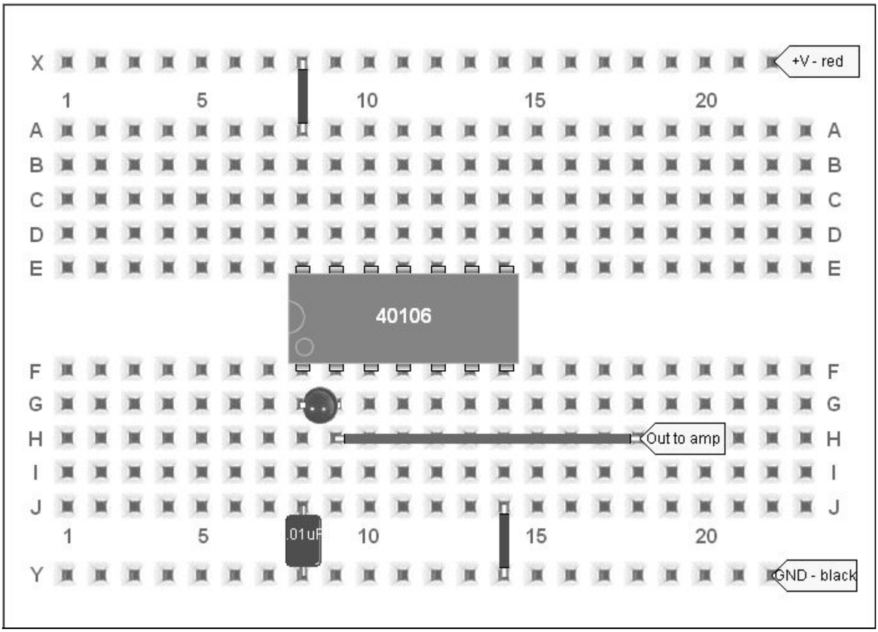
Then add the capacitor (.01 uf, sometimes marked 103, to start with):



Then add the resistor; try 100k (brown-black-yellow) as a starting point… since it's going across pins 1 and 2 of the IC and there's not much room, fold over one lead so both leads are sticking out in one direction, and trim them so you can stand it on it's end:



Then connect battery , red to the top rail and black to the bottom. Finally connect the signal to your amp (don't forget the ground, too) and listen. If you haven't got an amp at your workstation there's a super simple circuit you can use on the next page.

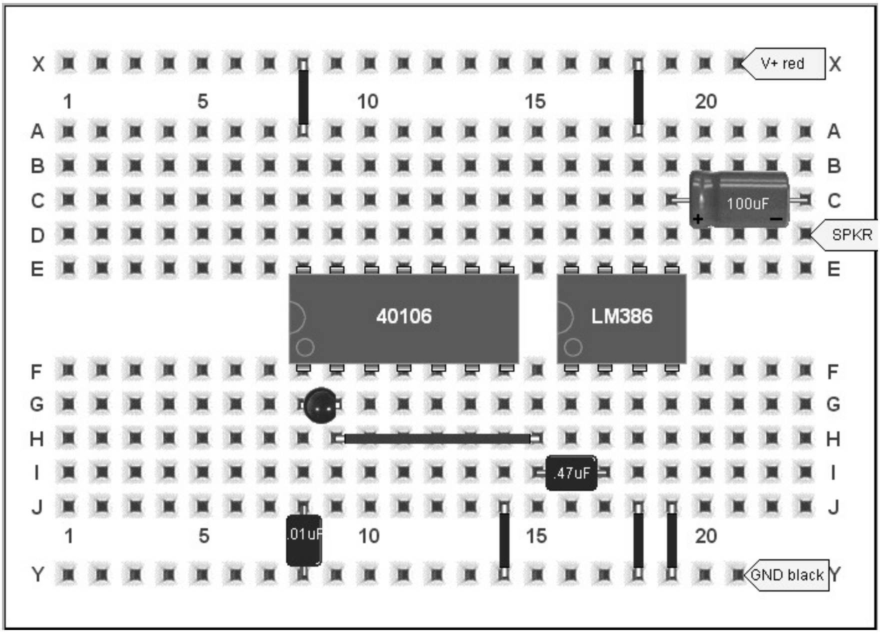


BEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEPPPPPPPPPPPPP

Hot damn. Oscillation! Once you've got a beep, you can start playing. . Replace the resistor with a photocell. Or wire in a pot (variable resistor) to control the pitch. Or, hold the two resistor leads in your fingers and squeeze to change your skin resistance. Or a combination. Play.

You can also change the capacitor value… swap in some different ones and see what happens. Sometimes the particular resistor/capacitor combination will be either too high or too low to hear… oops. Try something else. Somewhere between .001 and .1 uf should be OK.

Super Simple Mini Amp

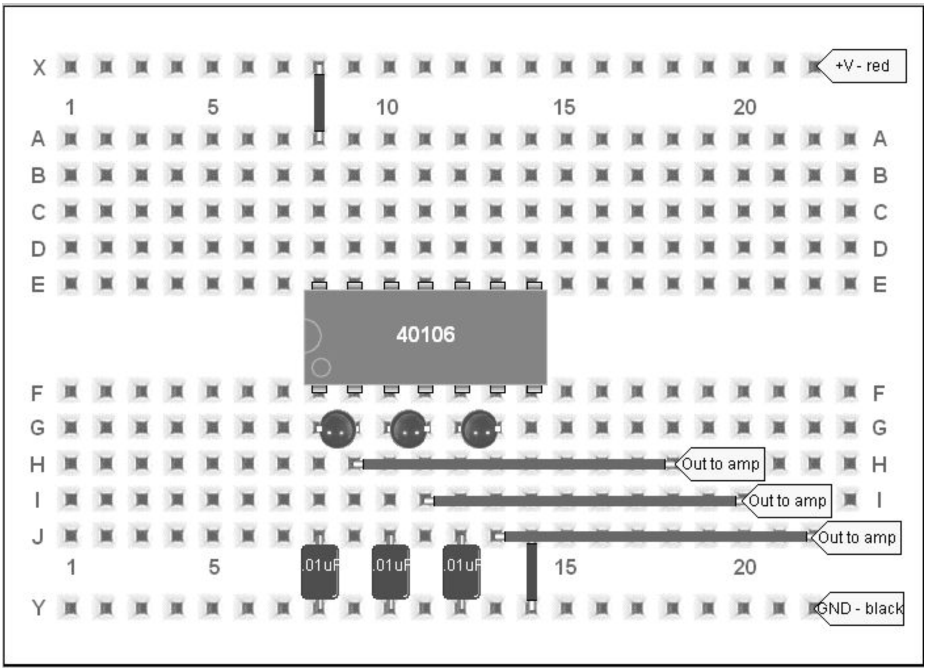


The LM386 is probably the simplest amp you can build. Pins 3 and 4 are tied to ground, pin 6 to V+. Pin 2 is the input (the capacitor stops it from getting overloaded) and pin 6 is the output. Hook up the two wires of a speaker to hear some noises (one wire as marked on the diagram, one to ground).

There are lots of mods you can add to improve the response of this circuit, and with a little bit of work it makes a respectable guitar practice amp. Plugging it into a big speaker gets you some suprising volume, considering it is a ½ Watt amplifier. Check out runoffgroove.com/ruby.html to see how you can get the best out of this $1.50 chip.

Fun x3:

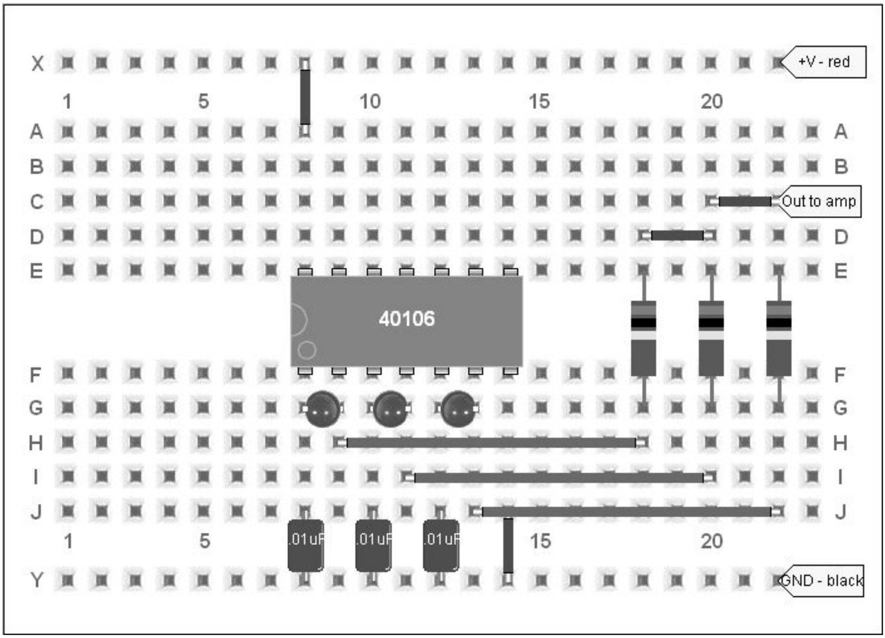
Hokay, since more is better, we'll build 2 more oscillators right next to the previous one. Like this:



Check each oscillator out one at a time, by listening to each output separately. If you use the exact same resistor/capacitor values, each oscillator should sound about the same; if you used different R/C combinations they should sound different. Get all 3 oscillators happy before continuing.

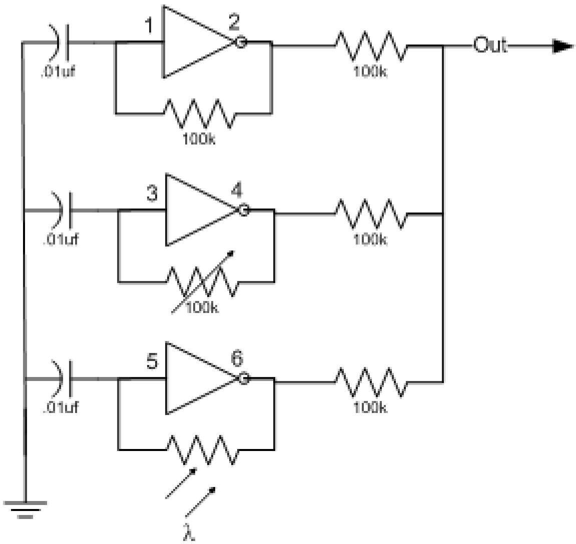
Mix 3 into 1:

But now we've got a problem: 3 outputs, one amplifier. We want to mix all three oscillators together. Just shorting them all together might work (for a while), but it's a bad idea--basically, the voltages coming *out* of each inverter are then going back *into* the outputs of the others, and the ins and outs fight… and eventually someone gets unhappy and craps out. That's why god invented Behringer and Mackie: so we could have mixers that let us connect outputs together without anyone getting unhappy. But we're cheap and our needs are few, so we'll just use 3 resistors as a simple mixer:



Sweet. All 3 oscillators signals are now mixed together, out to the amp. If you wanted to get fancy, you could replace the fixed mixer resistors with variable resistors (pots) connected as voltage dividers--essentially, you'd have a separate volume control for each oscillator…

Anyway, if you've used a couple of variable resistors (photocells or pots or touchpoints) in your oscillators, things should be getting interesting. BTW, here's a new schemo:



It's showing a fixed timing resistor on oscillator #1; a variable resistor (pot) on osc. #2, and a photocell (the arrows & greek y) on osc. #3. The 3 100k resistors on the right are the mixer resistors. Of course, you might have something different by now…

Building Blocks:

So we have oscillators, and we can change their frequency by changing the values of either the resistor or capacitors. In addition to changing them manually, we can also use one oscillator to control another oscillator. Once we start stringing circuits together, one circuit controlling another circuit… oh, boy.

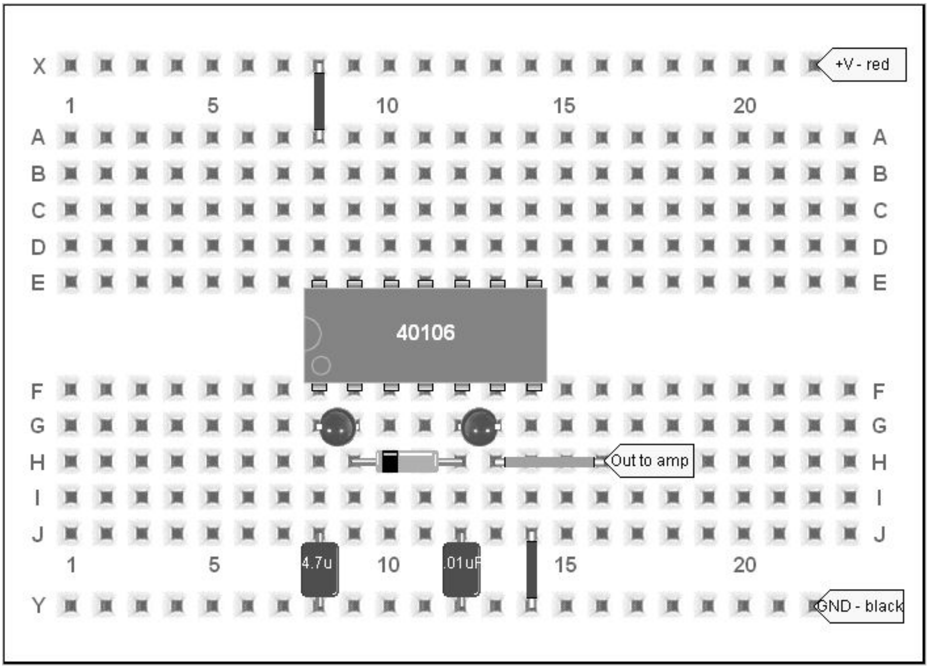
So we'll set up 2 oscillators: the first one will be really slow, and we'll use it to control the second one. Start with what you had for the last circuit, then:

Remove the 2nd oscillator (resistor & capacitor on pins 3 & 4, and their output)

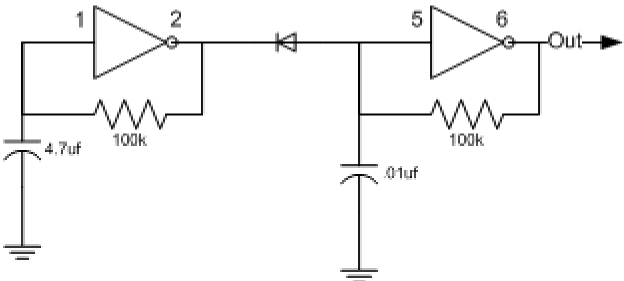
Swap the capacitor on the first oscillator for a bigger one to slow it down: try 4.7uf. That will be an electrolytic cap (the bigger can-shaped things), which are polarized, so make sure the negative side (marked) goes to negative/ground, and the positive side (longer lead) goes to pin 1.

Remove the output lead from oscillator #1 (pin 2). Now, use a diode to connect the output of #1 to the input of oscillator #3 (pin 5). Diodes are also polarized, to show which way they allow signal to flow… in this case, the banded end should go to pin2 of the IC (see picture). The diode keeps the signal flowing in only one direction, so osc. #3 doesn't feed back to osc. #1.

The circuit should now look pretty much like this:



And here’s the schemo:



You should be able to hear the first oscillator switching the tone of the second oscillator back and forth between low to high. Try using variable resistors and start monkeying with the rate of the first oscillator, then the frequency of the second… then both.

Now, let's speed up oscillator #1 by changing the capacitor back to .1uf or so. Now osc. #1 is switching #2 pretty fast; your ear can't keep up with it, and instead of hearing oscillator #2 jump discreetly between 2 tones, the frequencies start to interact… this is called Frequency Modulation, or FM… this is a very powerful technique, more about it next week.

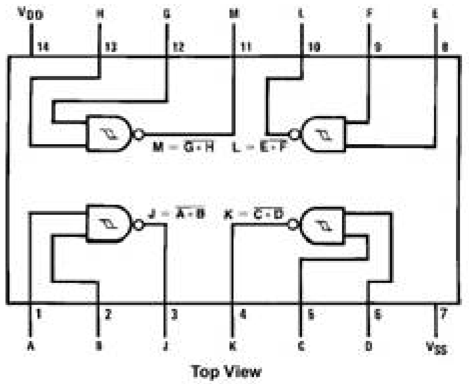
More to come

So those are some basics: oscillators, which can be controlled manually or which can control each other. We've only build 3 oscillators, but the chip can do 6. A sweet setup would be 3 pairs of FM oscillators with all three outputs mixed together… speed controls on the slow oscillators, photocells on the fast ones, individual volume controls… you get the idea. You can get some pretty complex sounds with just a few basic building blocks, repeated a few times.

4093 Oscillator(s)

Last week we built our first oscillators, based on the 40106 chip. Hopefully you were able to get several oscillators working, mixed some of the outputs together, and maybe even connected 2 oscillators together (using the diode) so that one oscillator controls (or “modulates”) the other. That basic building block allows hundreds of variants--stringing them together in different ways, mixing, and various ways of controlling--so don’t shortchange the possibilities of just that one chip, and keep playing.

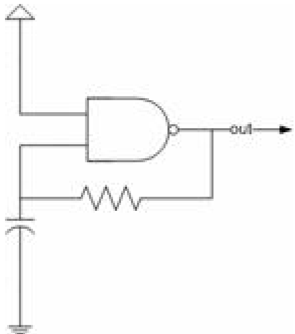
This week we’ll introduce a very similar oscillator using a different chip, which will allow you to connect them together in a slightly different way. (BTW, this again is straight out of the Nic Collins book, which I will recommend again.) The new chip is the 4093 quad NAND gate, and here’s its pin-out:



First, notice the circuit elements: 4 identical NAND gates, which implement a particular logic rule… Each of those bullet-shaped things is a gate, with 2 inputs (pin 1 and 2 for the first gate, for instance) and one output (pin 3 for the first one). Both inputs of a gate are the same (you can use whichever one is handiest for your layout), and each gate is identical. Last thing to check is the power: like the 40106, VDO (pin 14) is the positive power connection, VSS (pin 7) is the negative or ground.

Oscillators 1, 2…

So that's the IC, here's the schematic for our basic oscillator, using 1 inverter, 1 resistor, & 1 capacitor:

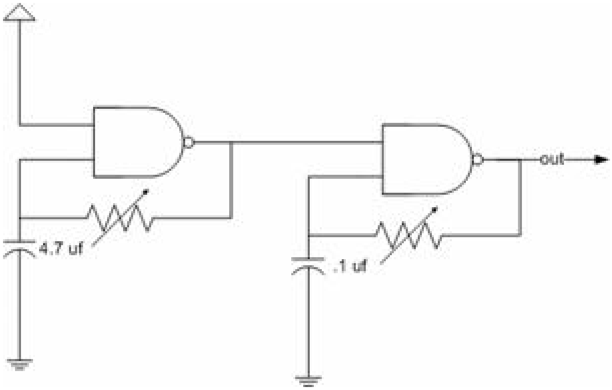


This should look very familiar; it's just like the 40106 oscillator, except that the inverter had one input and the gate has two. We'll have to supply a logic signal (high or low) to the new second input of the gate to control the oscillation. If that signal is low (0v), the oscillator won't go; if it's high (9v) it will--that's the trick we'll use when we start connecting oscillators together.

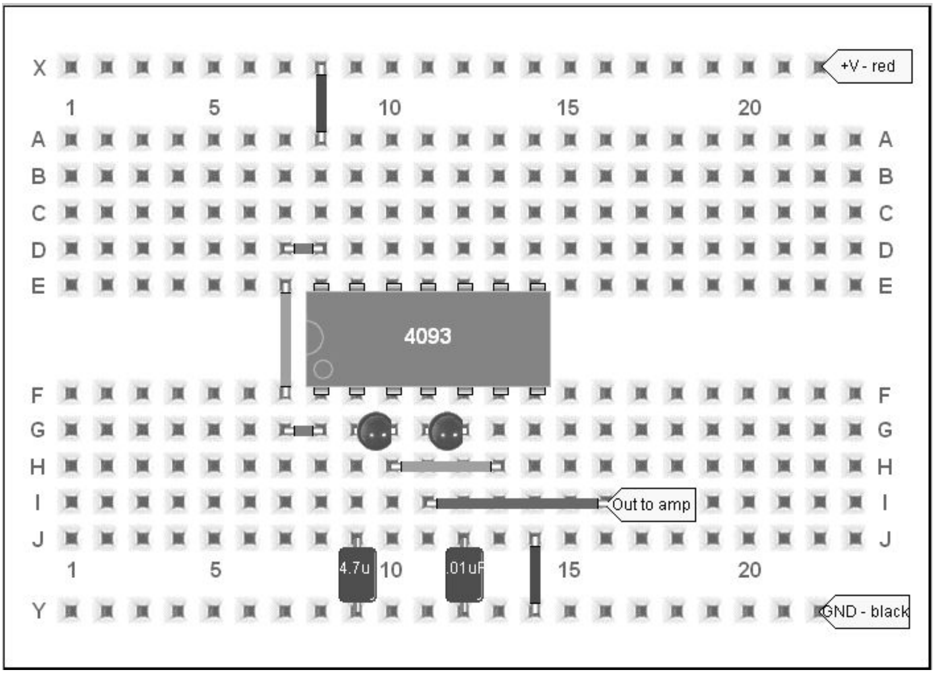
The schematic doesn't tell you which specific IC pins to use, but you can figure it out by referring to the pinout diagram. I usually pencil in the pin numbers on my schemo before I start, to cut down on the confusion. When I built it, I decided to use the first gate (1 & 2 for input, 3 for out). So go ahead and wire it up like last time, starting with the power connections, then the cap and resistor.

The red thing between pins 2 & 3 is the resistor; start w/ 100k, or variable (pot, photocell). This also shows 3 jumpers to pick up the power from pin #14 and apply it to pin #1--you can run just one wire, or use the double buss lines on the edges of the breadboard so you can have power and ground on both sides of the chip.

Power it up, make sure nothing smokes, and connect to your amp; it should sound pretty much like the 40106 oscillator. So what. Next step is to add a second oscillator using the second gate and connect them together. Here's your schemo:



One oscillator after the other. I used the next gate on the same side of the chip, pins 4, 5 & 6. The schemo shows a large value cap for the first oscillator, so it will be slower. Anything between 1 and about 25uf will do; so swap in an electrolytic cap, making sure to watch the polarity (negative to ground). Anyway, here's (one possible) layout:



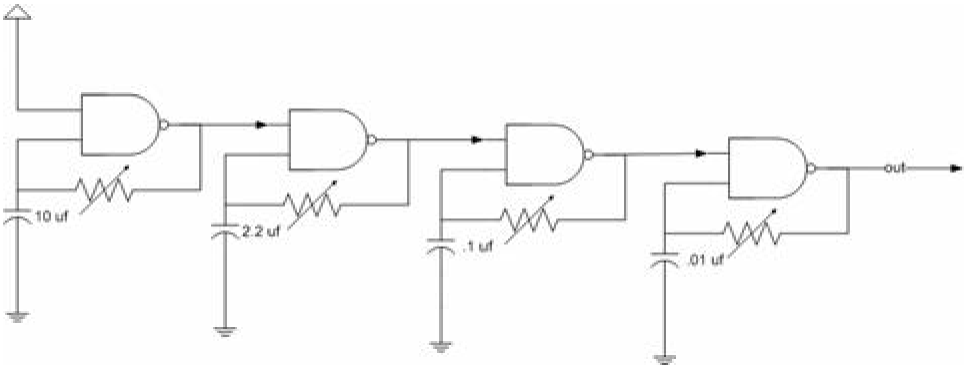
The yellow jumper is the connection between oscillator 1 and 2. You should hear oscillator 2 beeping on and off, the rate of beeping being determined by oscillator 1.

Here's what's going on: remember how we had to tie one gate of the first oscillator "high" (to 9v) for the circuit to go? By connecting the output of the first oscillator to one side of the second gate, it turns the second oscillator on and off, or "gates" it. Beep beep beep.

Try different combos of caps… a couple of big caps can lead to some interesting rhythmic patterns; small caps can get more into screeching weasel territory. Either way, having some kind of variable resistors is key to keeping things interesting and making it playable.

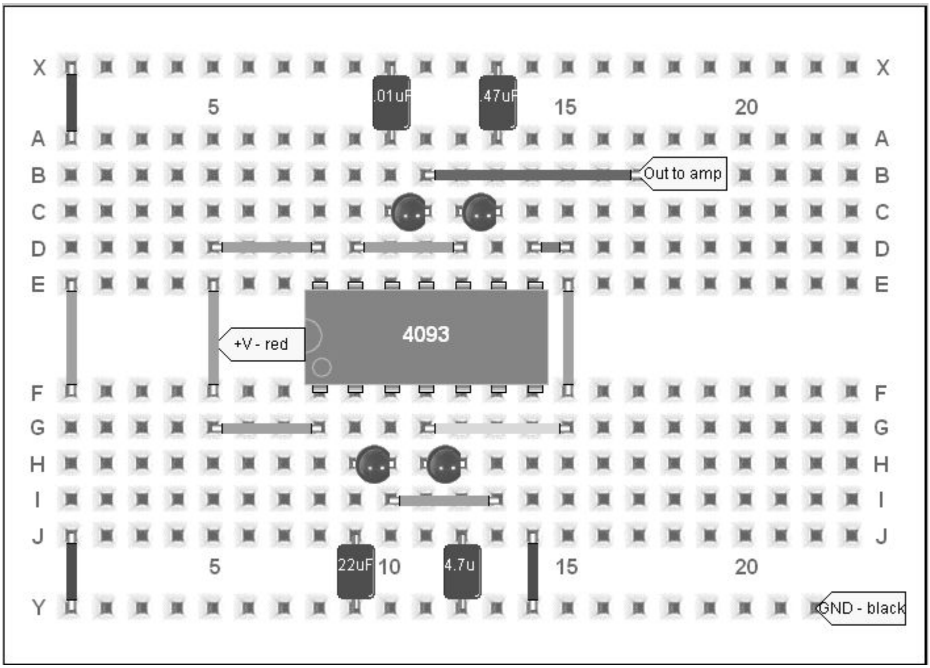
Four is better

So we got 4 gates on this chip, let's use 'em:



One oscillator controlling another controlling another…. that's gotta be good, right? Like last week, it's easiest if you build one oscillator at a time, make sure it's working, and then adding it to the chain. With the cap values shown, the oscillators get progressively faster, which might be what you want or it might not. Build it up and see.

Something like this, perhaps:



Variations:

There's a bunch of things you could try at this point:
Different combinations of caps
Photocells or pots for various resistors
Tap the signal from all 4 oscillators in the chain, and mix them together…
2 pairs of gated oscillators… stereo, or mix the outputs together
Build 4 separate low frequency oscillators… mix the outputs together using unequal resistors… rhythmic pulses with accents.
You still have your 40106 oscillators, right? Connect their outputs to the gate ins of some of the 4093s.
16 chips, 64 oscillators, each oscillator modulating 2 other oscillators in a giant ring, and whipped cream … eh, sometimes more is not better.

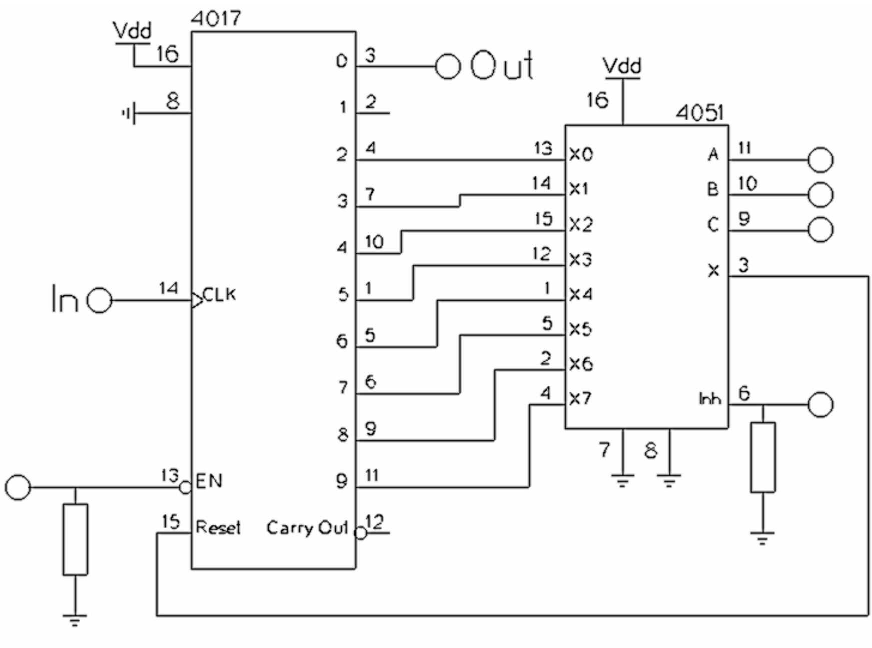
Electro-music Lunetta Forum

electro-music.com/forum/forum-160.html

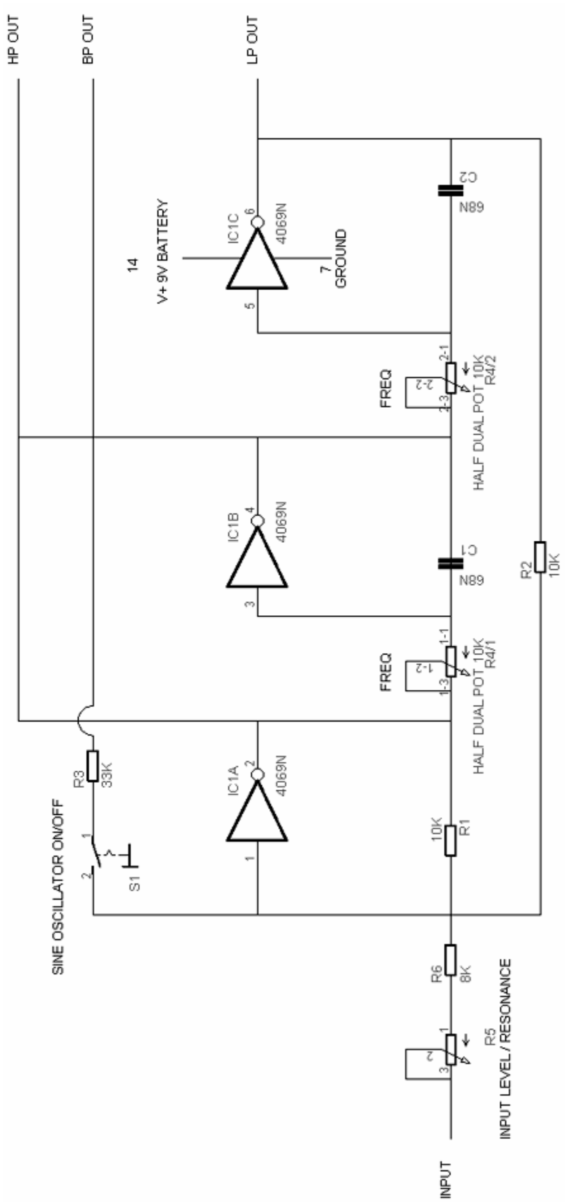
The operation of these circuits is a bit more complex to understand, but they make great sounds so are definitely worth experimenting with.

Melody generator

When you send an audio or super-audio clock to the input, the output oscillates at 1/2, 1/3, 1/4, 1/5, 1/6, 1/7, or 1/8th the frequency, depending on the states of control inputs A, B, and C. If you drive those three control inputs with oscillators, the output moves through a sequence of tones. “EN” input can be pulsed on and off to create tremolo and modulation effects.

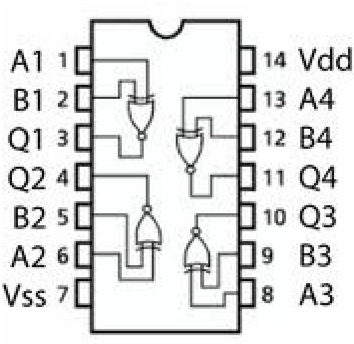


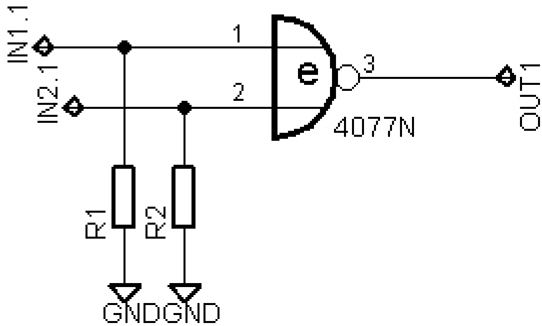
Filter
This is probably the simplest active LP/HP filter out. Tweak til satisfied.


HP OUT
BP OUT
LP OUT
14
V+ 9V BATTERY
IC1C
4069N
7
GROUND
C2
68N
FREQ
HALF DUAL POT 10K
R4/2
IC1B
4069N
C1
68N
R2
10K
FREQ
HALF DUAL POT 10K
R4/1
IC1A
4069N
R3
33K
SINE OSCILLATOR ON/OFF
S1
R1
10K
R6
8K
R5
INPUT LEVEL / RESONANCE
INPUT

Psuedo Ring Modulator

Super easy psuedo ring modulator – a great way to add some flavour to your tones. You can make four 2-input modulators from the one chip. This is designed for digital signals. If you want to run general audio into it you'll have to square up the waves first with an LM386. Refer to the PWM circuit in the back of the *Schemtic to Reality* booklet.





Experiment with different combinations, try sending 4 different oscillator signals into A1, B1, A2, and B2 and sending the outputs Q1 and Q2 to A3 and B3.

Fun With Sea Moss

milkcrate.com.au/_other/sea-moss

4051 Arpeggiator

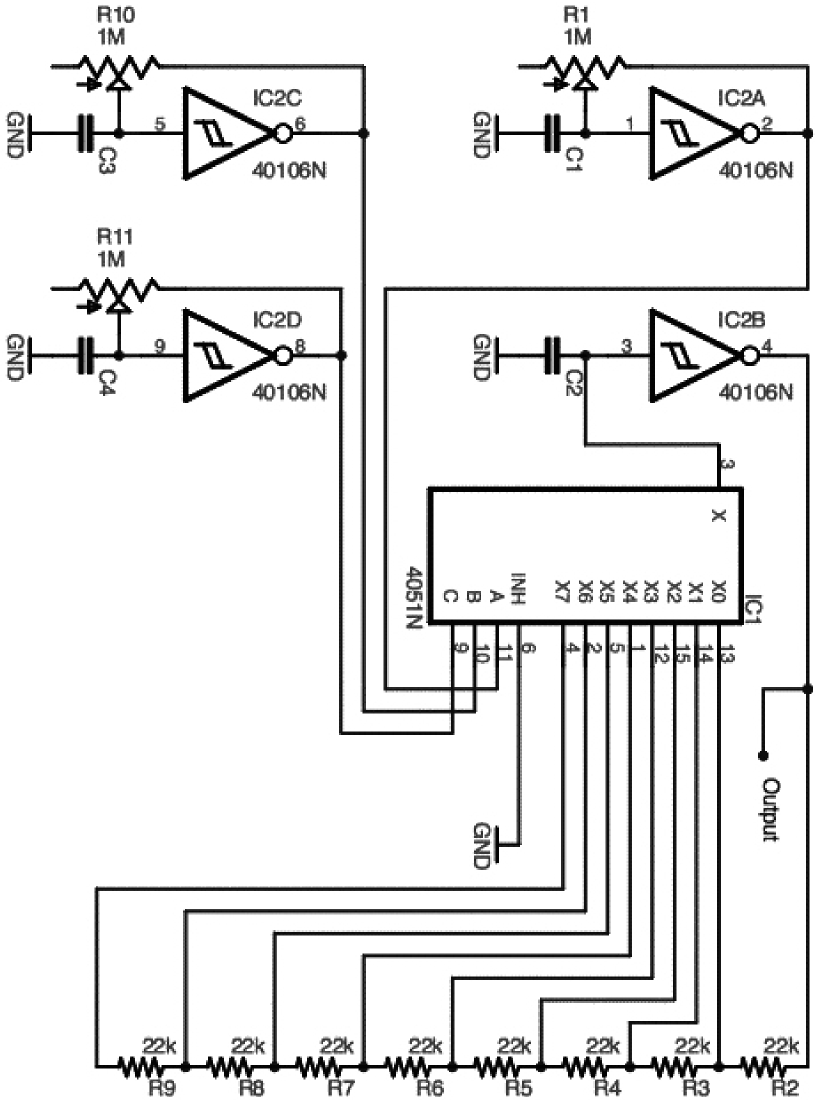
Parts

40106 IC
4051 IC
0.1uF capacitor
0.22uF capacitor x 3
1MΩ potentiometer x 3
22KΩ resistors x 8

Theory

The state of the three control oscillators in combination determines which gate of the 4051 is open. A resistance ladder creates different pitches for the fourth oscillator (whose output is connected to the overall output) depending on which gate is currently active. Resistors in series have a sum resistance. When gate 7 is active, the resistance is at maximum (ie. 8 x 22KΩ). When gate 0 is active, the resistance is at mimimum (ie. 1 x 22KΩ). By changing the frequencies of the three oscillators, interesting control structures can appear in relation to which pitches are selected when.

Schematic



R10
1M
IC2C
40106N
R1
1M
IC2A
40106N
R11
1M
IC2D
40106N
IC2B
40106N
GND
C3
C1
C4
C2
4051N
IC1
X
INH
A
B
C
X0
X1
X2
X3
X4
X5
X6
X7
Output
22k
R9
R8
R7
R6
R5
R4
R3
R2

4040 4051 Sequencer

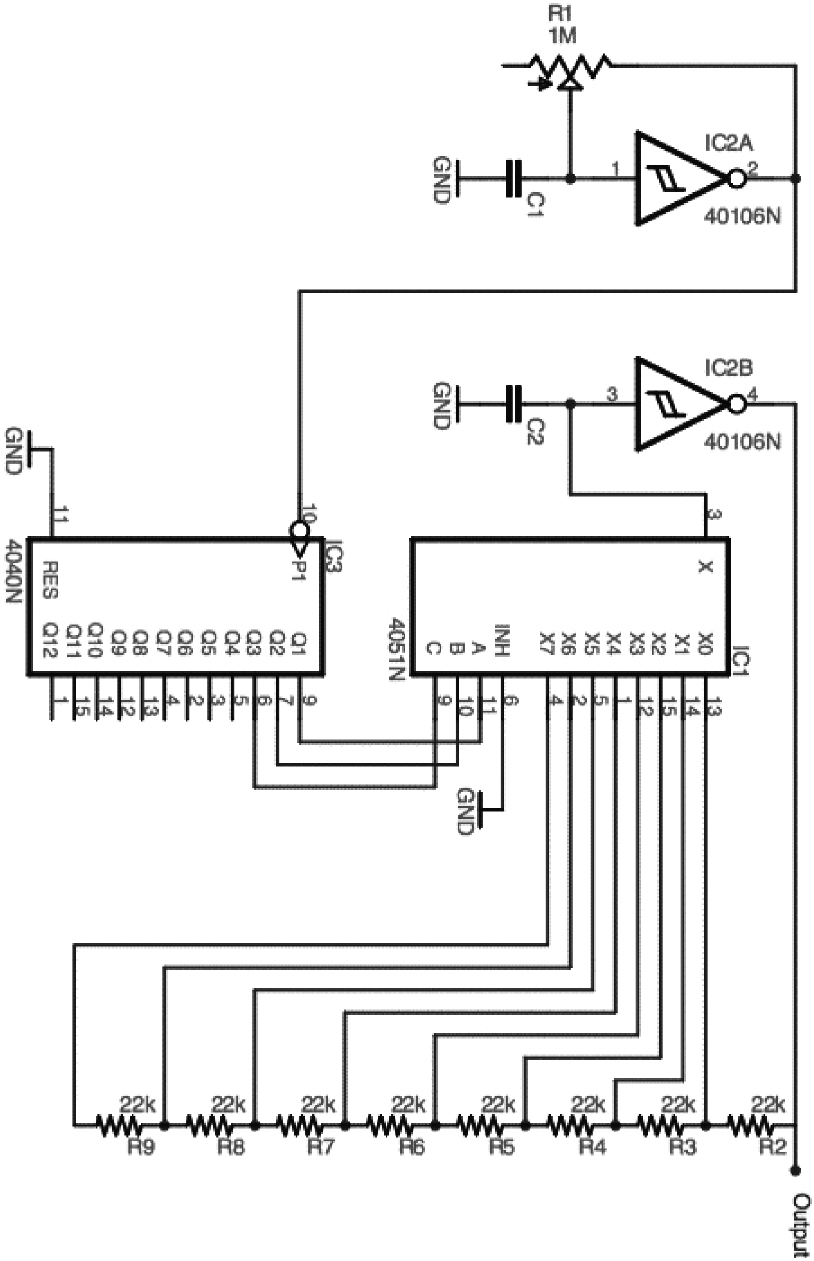
Parts

40106 IC
4040 IC
4051 IC
0.1uF capacitor
0.22uF capacitor
1MΩ potentiometer
22KΩ resistor x 8

The 40106 is used to create two oscillators. The first oscillator is connected to the clock input of the 4040. The first three outputs of the 4040 are connected to the address pins of the 4051 and thus 'step through' the eight gates.

A resistance ladder creates different pitches for the second oscillator (whose output is connected to the overall output) depending on which gate is currently active. Resistors in series have a sum resistance. When gate 7 is active, the resistance is at maximum (ie. 8 x 22KΩ). When gate 0 is active, the resistance is at mimimum (ie. 1 x 22KΩ).

It is recommended to use 1% or 2% (ie. not 5%) accurate resistors for the pitch values if planning to make more than one sequencer to be played at the same time. By rearranging the relationship between the 4040 output pins and the 4051 address pins, the sequence of the pitches will change accordingly. By replacing the resistance ladder with a 8 pots, the pitches will be changeable in real time.


R1
1M
IC2A
40106N
GND
C1
IC2B
40106N
GND
C2
GND
IC3
4040N
RES
P1
Q1
Q2
Q3
Q4
Q5
Q6
Q7
Q8
Q9
Q10
Q11
Q12
IC1
4051N
X
X0
X1
X2
X3
X4
X5
X6
X7
INH
A
B
C
GND
22k
R2
R3
R4
R5
R6
R7
R8
R9
Output

Eight Stage Custom Waveform Generator

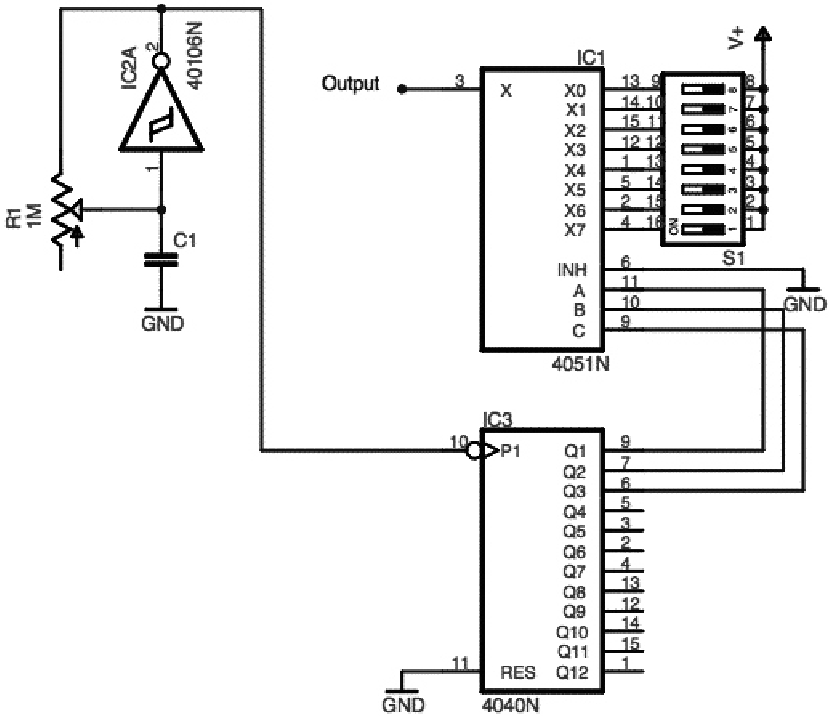
Parts list

40106 IC
4040 IC
4051 IC
8 way single pole, single throw dip switch
1M potentiometer
0.1uF capacitor

This is a lateral adaptation of the basic sequencer. Instead of controlling the resistance that controls the frequency of an oscillator, an eight way switch allows voltage to either pass through or not over eight points in time, forming an eight stage one-bit custom waveform generator. The positions of the eight switches are a direct representation of the resulting waveform. R1 controls the frequency of the custom waveform.

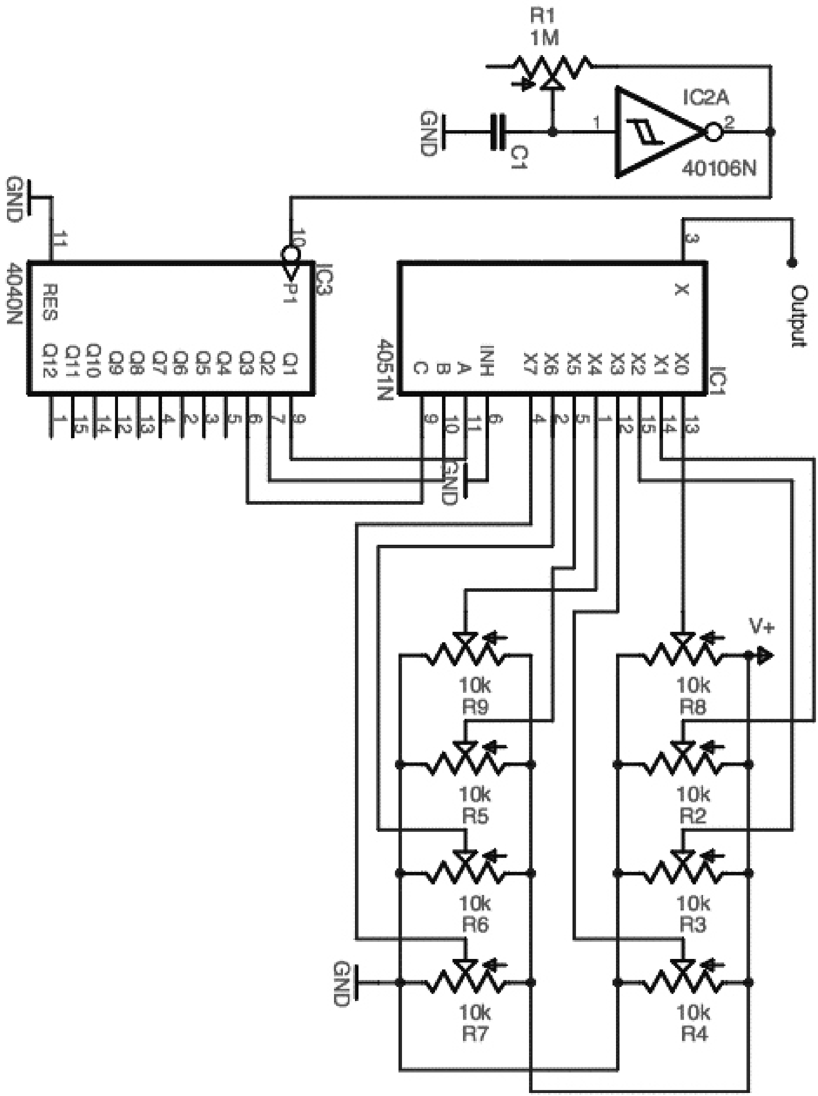
This circuit can be made with or without the dip switch. If it is made with the dipswitch, the input gates on the 4051 are left floating and this affects the waveform. A true one-bit waveform can only be achieved by tying the floating lines to ground. This can be done by directly connecting the gates to either high or low to create a custom waveform. However, the dipswitch allows for an easier to use interface.

Schematic



IC2A
40106N
2
1
R1
1M
C1
GND
Output
3
IC1
X
X0
X1
X2
X3
X4
X5
X6
X7
INH
A
B
C
4051N
V+
S1
GND
IC3
10
P1
Q1
Q2
Q3
Q4
Q5
Q6
Q7
Q8
Q9
Q10
Q11
Q12
RES
11
GND
4040N

Substituting the DIP switch for pots gives greater control over the waveform:



Links

Favourites

fluxmonkey.com
nicolascollins.com
electro-music.com/forum/forum-160.html
 milkcrate.com.au/_other/sea-moss

General electronics

mysite.du.edu/~etuttle/electron/elecindx.htm

Guitar effects

Very active community of effects builders:
diystompboxes.com/smfforum
A massive resource of schematics and PCB layouts: tonepad.com
Articles, circuits, parts; get some scientific backup for you gear snob tendencies: muzique.com
Just about very pedal ever made explained: geofex.com
Schematics for stompbox versions of classic amps:
runoffgroove.com
Dozens of really great, really simple circuits folkurban.com

Purchase

Analog synth, theremin, & effects kits: paia.com
Guitar effects: buildyourownclone.com
Arduino based noise gadgets: bleeplabs.com
Vintage/rare/generally amazing guitar & amp parts and kits:
smallbearelec.com
Bug Brand Electronics - bugbrand.co.uk

People

Sebastian Tomczak - little-scale.blogspot.com
Adachi Tomomi - adachitomomi.com
Alex Baker - alexbaker.co.uk
Dr. Offset - droffset.blogspot.com
Eric Archer - ericarcher.net

Folktek - folktek.com
Gijs Gieskes - gieskes.nl
Ian Baxter - ianbaxter.net
Ithai Benjamin - ithaibenjamin.com
MaoMakMaa - maomakmaa.blogspot.com
Mike Walters' Mystery Circuits - mysterycircuits.com
Phil Archer - philarcher.net
Tiny Dazzler - tinydazzler.blogspot.com
Todd Bailey - narrat1ve.com
Tommy Stephenson & Patrick McCarthy - rothmobot.com
Tuomao Tammenpaa - misusage.org
Vasco Alvo - vascoalvo.com

Supplies

Amateur-friendly parts and kits, good prices – mindkits.co.nz
Cheap, sometimes dubious quality – surplustronics.co.nz
Expensive but comprehensive selection – jaycar.co.nz
Bafflingly large selection – rs-online.com