Basic Electronics for Amateur Radio

# Audio Oscillators

by

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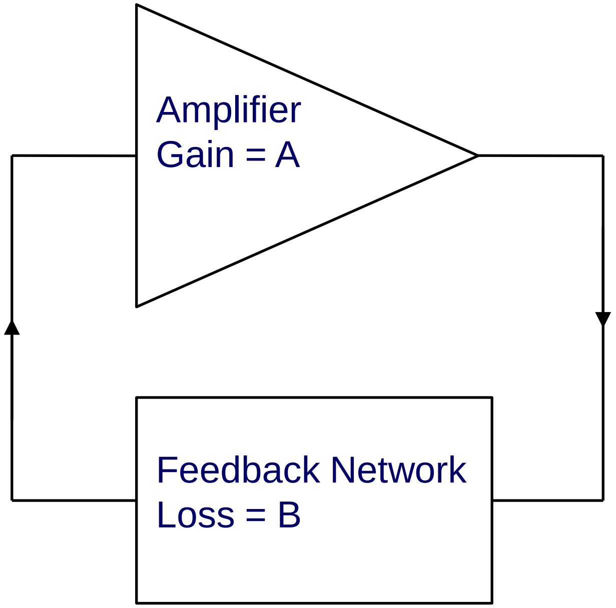
# Introduction

We will discuss the design of a phase shift oscillator and look briefly at a few other oscillator types.

# The Barkhausen Criteria (Simplified version)



For continuous oscillation,

1 The gain around the amplifier/feedback loop must be one.

ie $A \times B = 1$

2 The phase shift around the loop must be 0 or an integer multiple of 360 degrees

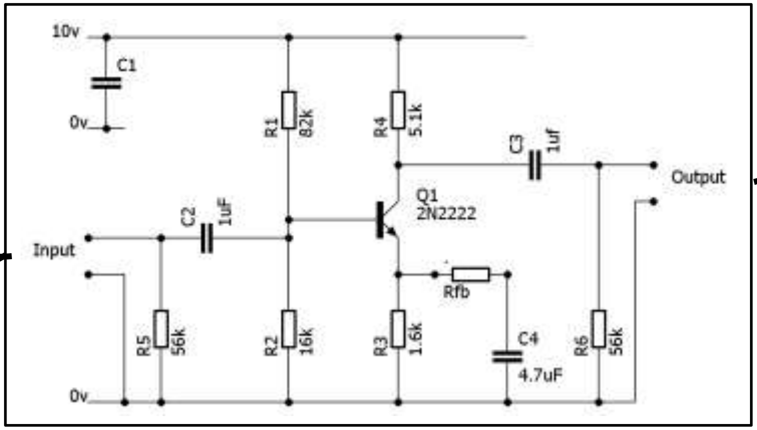
ie the feedback must be positive.

# The Common Emitter Amplifier

The common emitter amplifier inverts the signal, effectively creating a 180 degree phase shift for a sine wave.

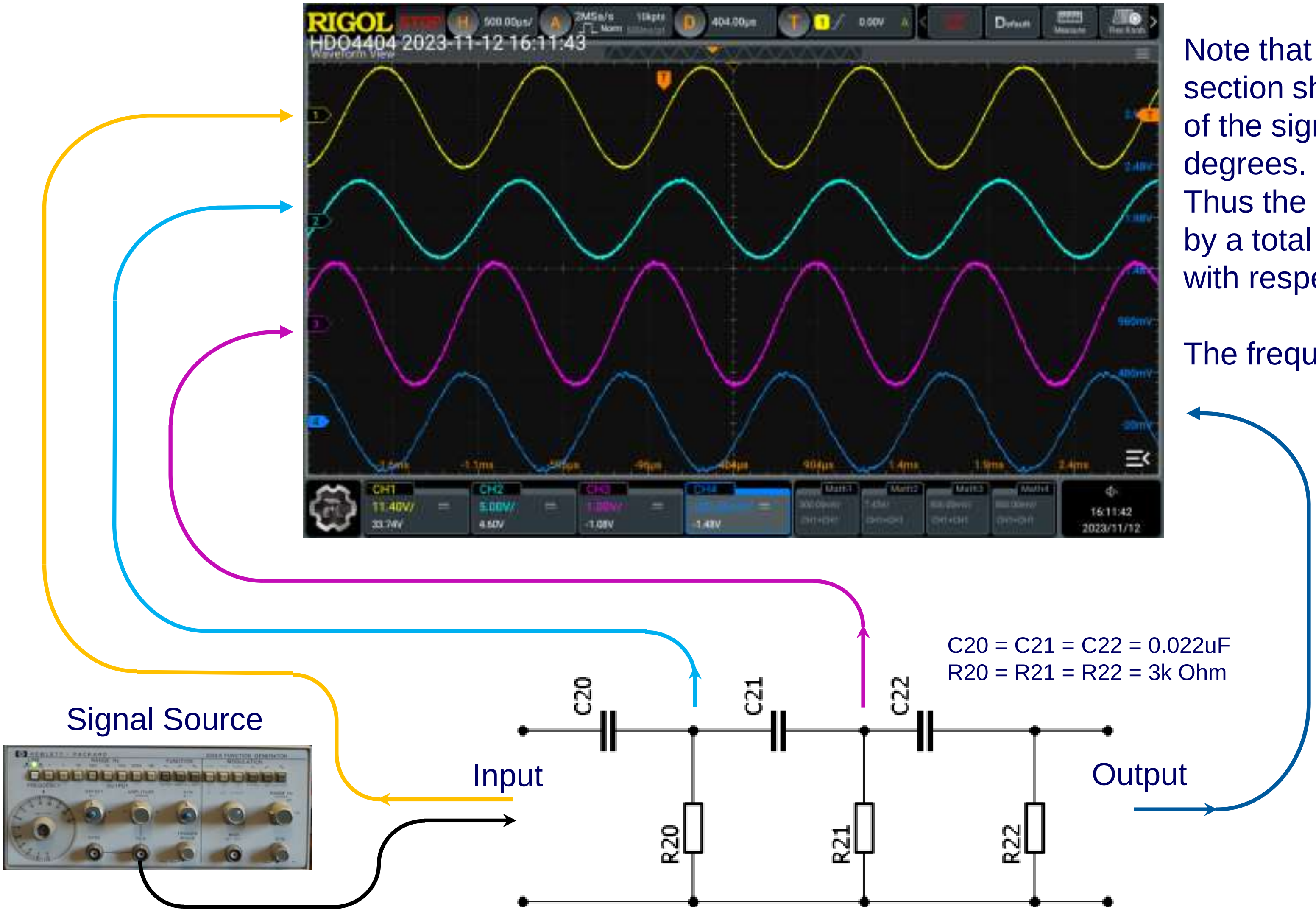
Measuring Device

Signal Source



Common Emitter Amplifier

# The Phase Shift Circuit Does This:



Note that each C-R section shifts the phase of the signal by 60 degrees.
Thus the output is shifted by a total of 180 degrees with respect to the input.

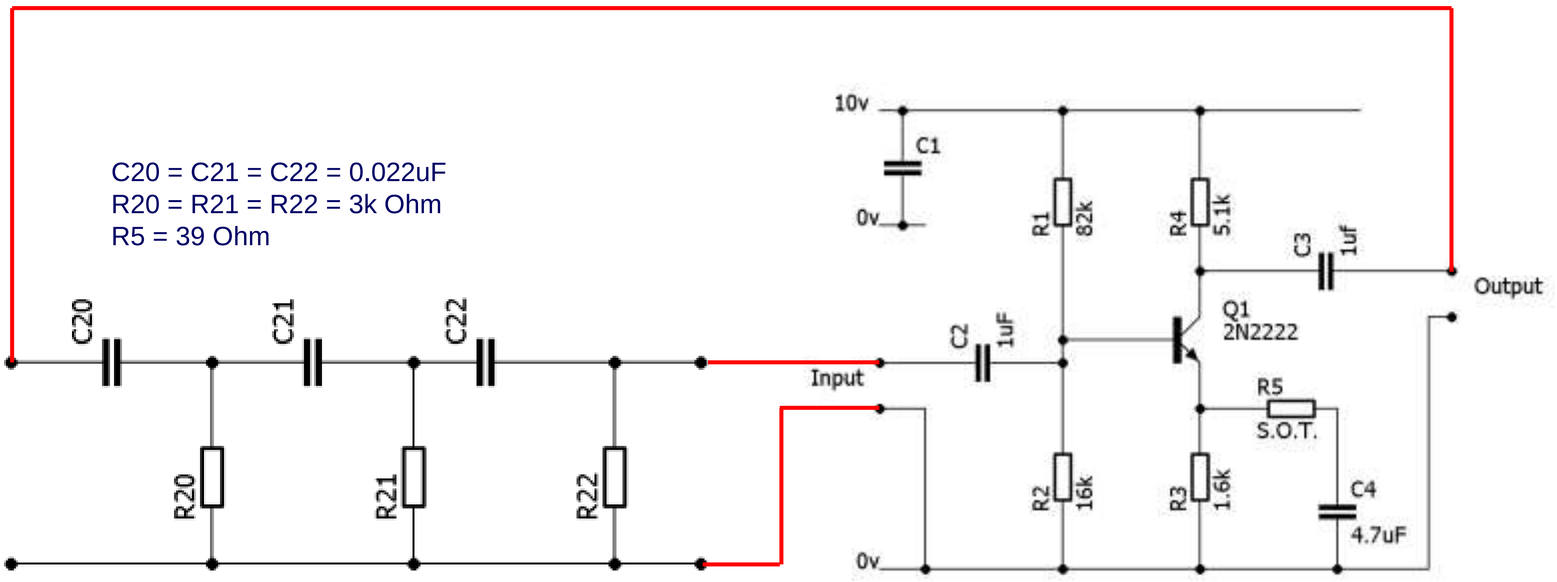
The frequency is 1050 Hz

C20 = C21 = C22 = 0.022uF
R20 = R21 = R22 = 3k Ohm

Three stage Phase Shift Network

# Basic Phase Shift Oscillator

Connect the amplifier and the phase shift network together, set the gain of the amplifier (must be 29 or greater), and it will oscillate.



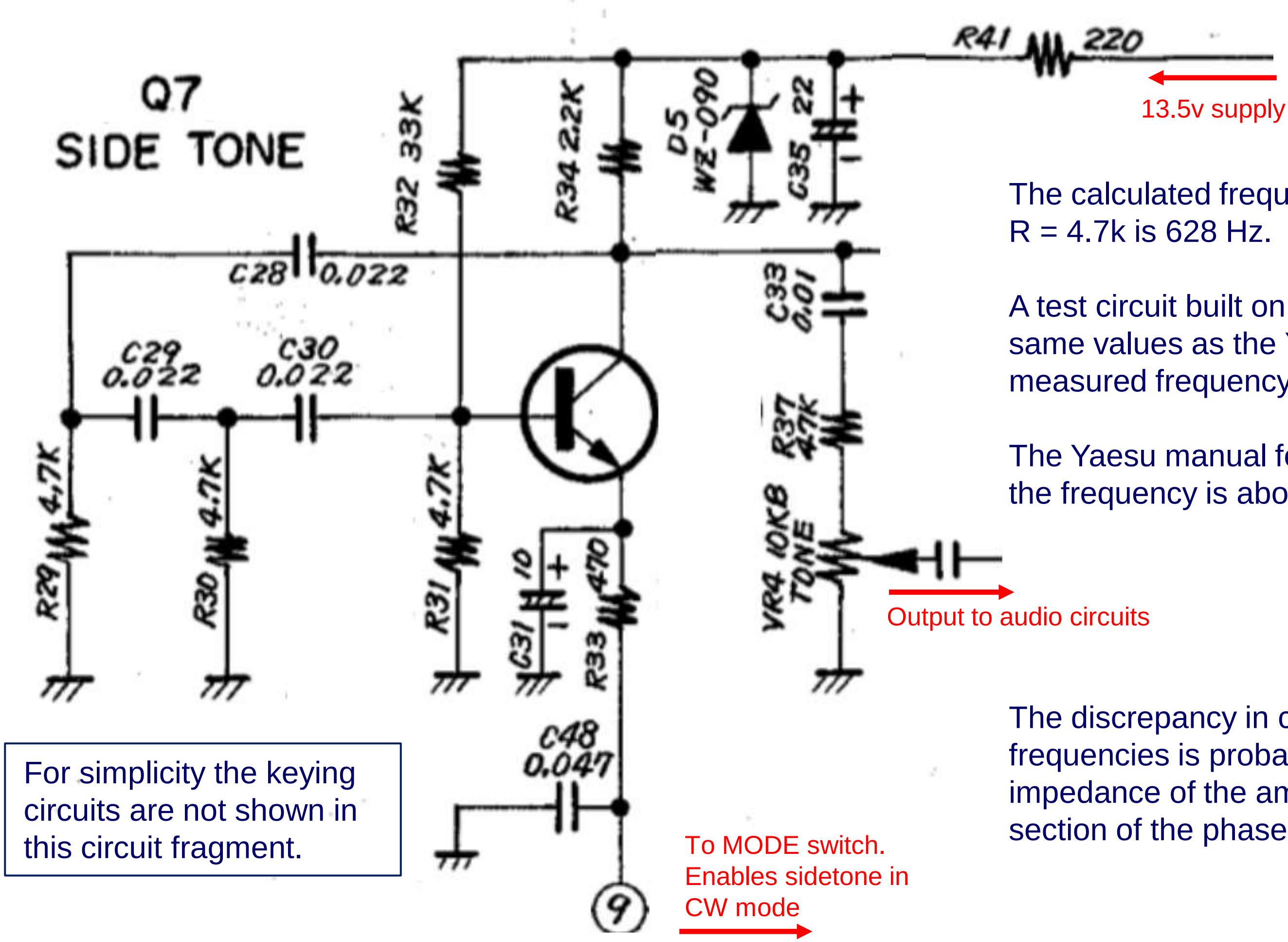
C20 = C21 = C22 = 0.022uF
R20 = R21 = R22 = 3k Ohm
R5 = 39 Ohm

Using the standard formula for a three stage phase shift oscillator,
$(f = \frac{1}{2\pi RC\sqrt{2N}})$ the calculated frequency will be 984 Hz.
The measured frequency was 942 Hz.

# On the ‘scope

Yellow trace is the waveform at the transistor collector, (~ 2.45v p-p)
And the blue trace is the waveform at the transistor base. (~ 60mV p-p)

# A Real World Example (Yaesu FT101 sidetone oscillator)



13.5v supply

Output to audio circuits

To MODE switch. Enables sidetone in CW mode

The calculated frequency for C = 0.022uF and R = 4.7k is 628 Hz.

A test circuit built on a breadboard using the same values as the Yaesu circuit gave a measured frequency of 811 Hz.

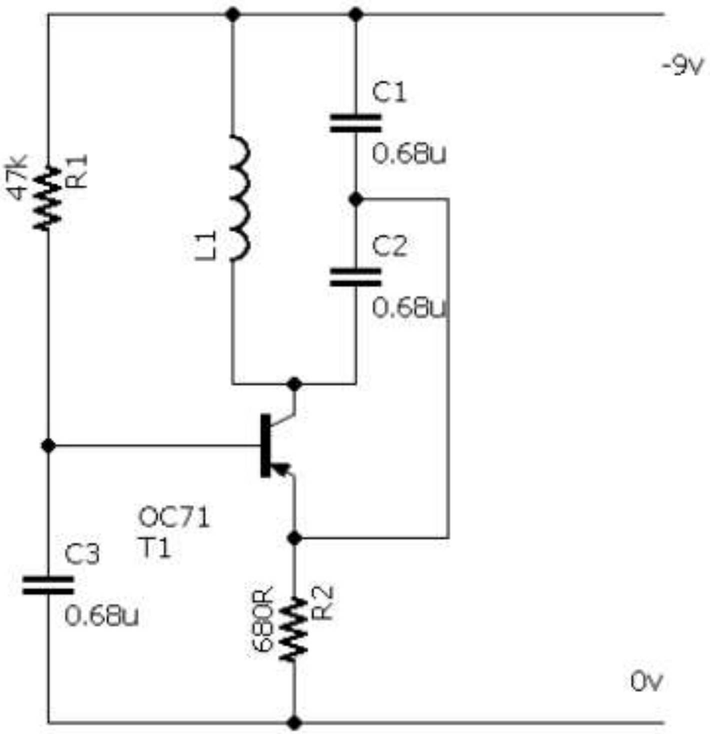
The Yaesu manual for the FT101 states that the frequency is about 800 Hz.

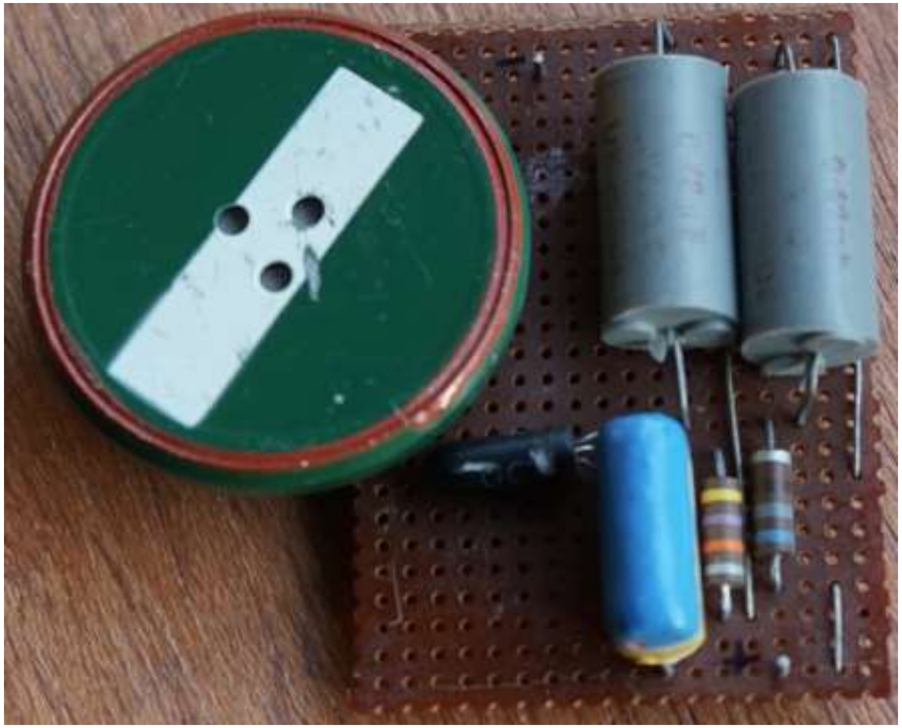
The discrepancy in calculated and measured frequencies is probably due to the input impedance of the amplifier loading the final section of the phase shift network.

For simplicity the keying circuits are not shown in this circuit fragment.

# A Simple Morse Practice Oscillator

A design from an early 1960s Practical Wireless magazine.
Uses an OC71 germanium PNP transistor.
This circuit using a tapped capacitor, is a variation of the colpitts  oscillator circuit.



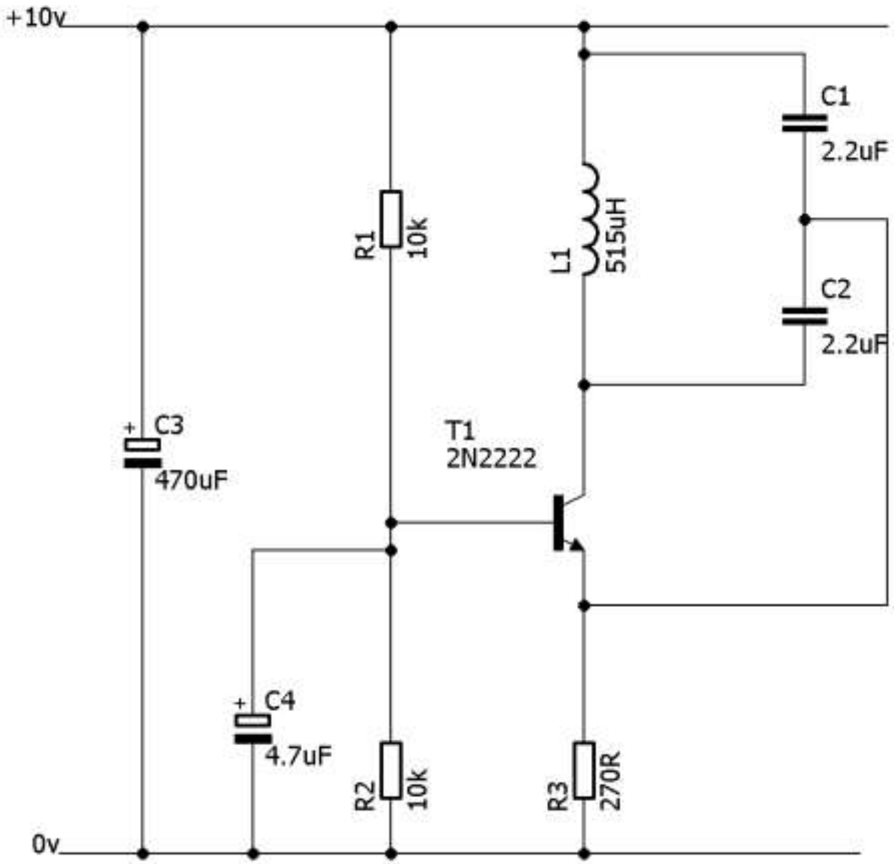


# On the ‘scope

Yellow trace is the waveform at the transistor collector,
And the blue trace is the waveform at the transistor emitter.

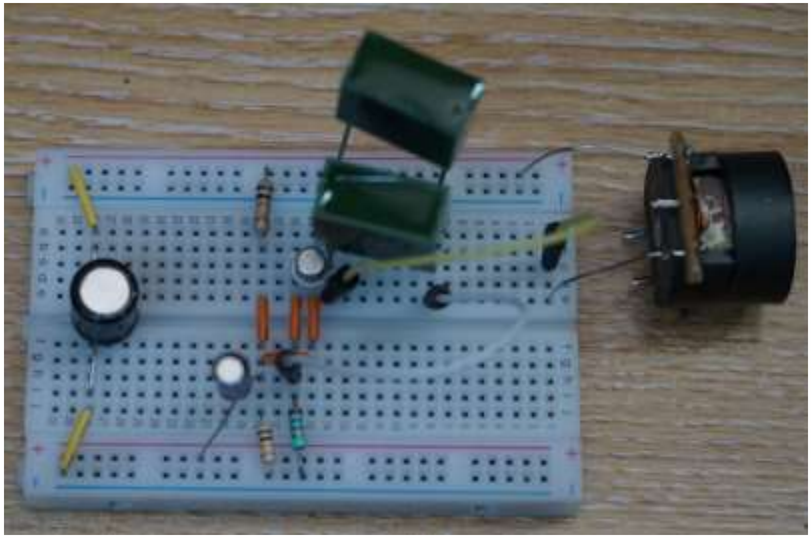
# Try again…

Using an inductor rather than a telephone earpiece and a silicon NPN transistor with more robust bias circuit.



A quick calculation using values of
L = 515uH and
C =1.1uF(2 x 2.2uF in series)
gives a frequency of 6.722 kHz.

The measured frequency was 6.666 kHz.



# And back on the ‘scope

Yellow trace is the waveform at the transistor collector,
And the blue trace is the waveform at the transistor emitter.
More recognizable as sine waves, as we would expect.

HDO4404 2023-11-16 15:45:09

H 100.00μs/

A 10MSa/s 10kpts Norm

D 240.00ns

T 6.26V

Freq(C1) 6.6666kHz

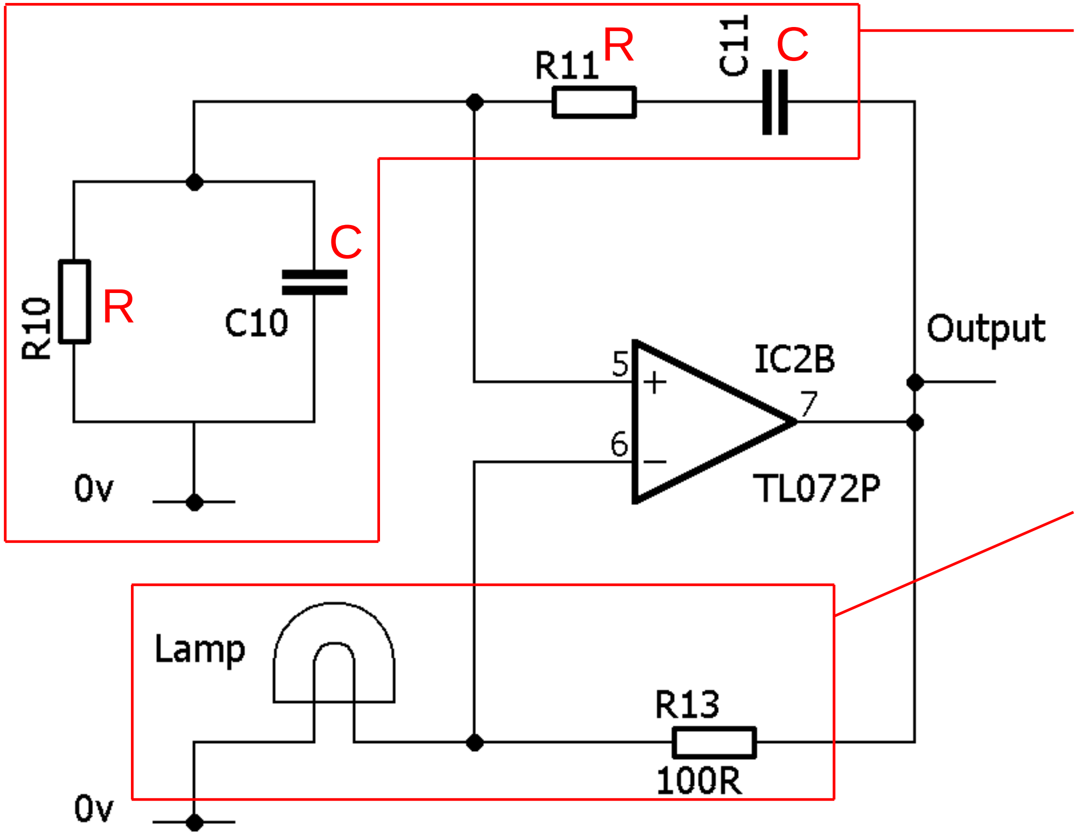
CH1 5.00V/ 0.00V 20MHz

CH2 2.00V/ -8.00V

CH3 50.00mV/ 0.00V

CH4 50.00mV/ 0.00V

# Wien Bridge Oscillator



Often used in test equipment such as audio signal generators.

The frequency determining components are C10, C11, R10 and R11.

The output frequency $F = \frac{1}{2\pi RC}\ kHz$

Where C is in uF, and R is in kOhm

When an adjustable frequency is required R10 and R11 are combined into a dual gang variable potentiometer.

In normal operation, the amplifier will have a gain of 3.

The lamp and R13 provide gain adjustment to stabilise the amplitude of the oscillation and give a clean sine wave output.

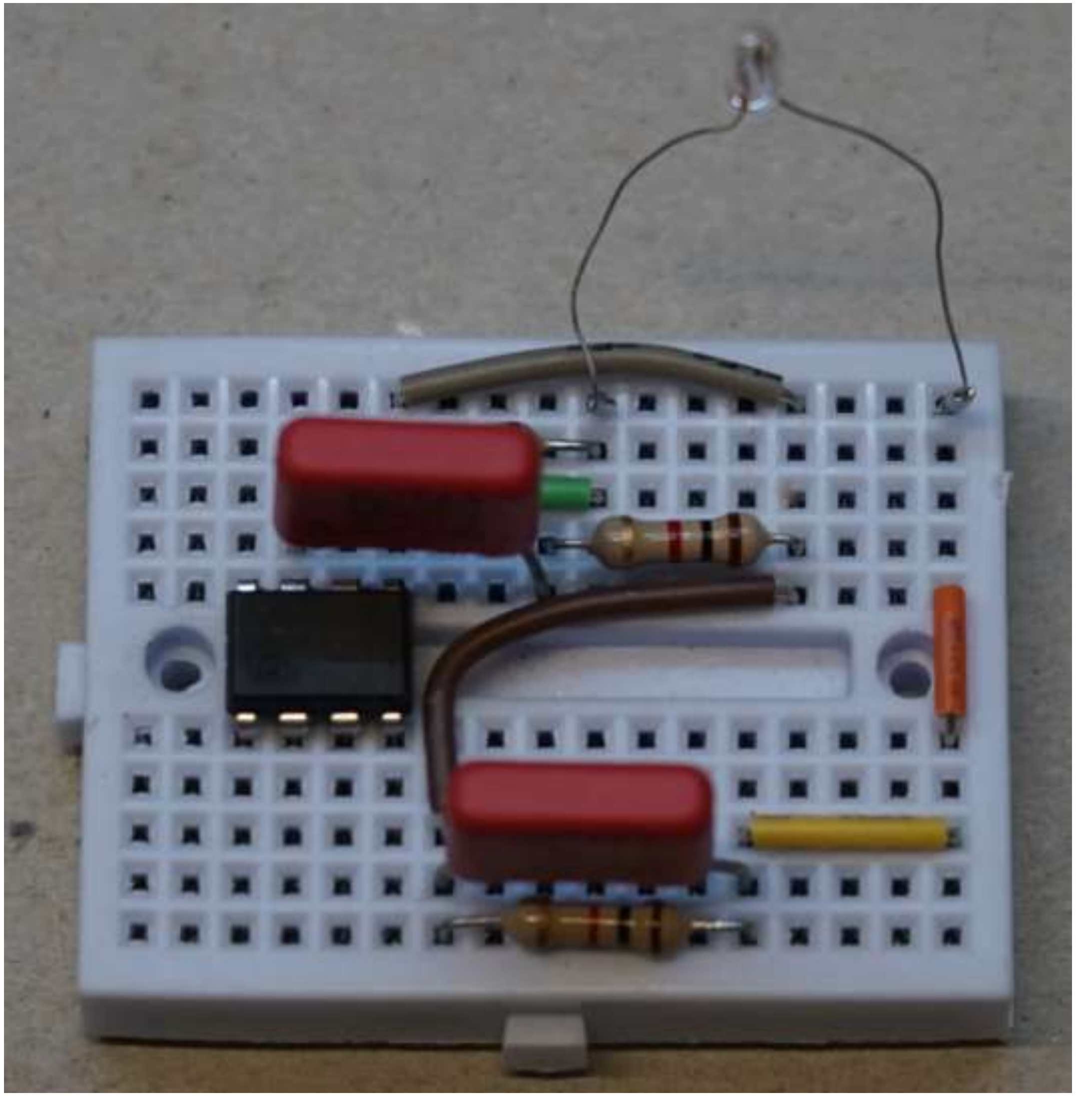
In the demonstration circuit R and C had values of 1kOhm and 0.22uF, giving a calculated frequency of 723 Hz.

The measured frequency was 739Hz.

# On the ‘scope

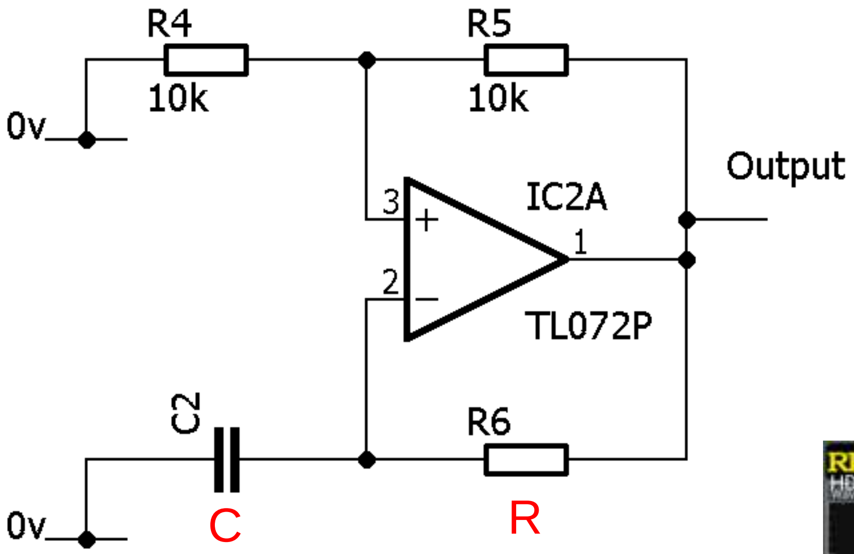

RIGOL
STOP
H 500.00µs/
A 2MSa/s 10kpts
Norm
D 0.00s
T 1 0.00V
Default
Measure
Flex Knob
HDO4404 2023-11-24 16:33:24
Waveform View
Result
Counter(C1)
739. Hz
Type Frequency
3V
2V
1V
-1V
-2V
-3V
-2ms
-1.5ms
-1ms
-500µs
0s
500µs
1ms
1.5ms
2ms
CH1 1.00V/ 0.00V 20MHz
CH2 500.00mV/ 0.00V
CH3 50.00mV/ 0.00V
CH4 50.00mV/ 0.00V
Math1 500.00mV/ CH1+CH1
Math2 500.00mV/ CH1+CH1
Math3 500.00mV/ CH1+CH1
Math4 500.00mV/ CH1+CH1
16:33:23
2023/11/24

# On the breadboard



The lamp used in the amplitude stabilizing circuit was a 12v 60mA type.
RS Part No 360-7913

# Op-amp Relaxation Oscillator



Yellow trace is the waveform at the output (pin1) of the Op-Amp.
The blue trace is the waveform at the inverting input (pin 2) of the Op-Amp.

R = 4.7k, C = 0.1uF, Fout = 967 Hz (calculated)

Output Frequency $F = \frac{10\text{^}3}{2.2 \times C \times R}$ kHz

Where C is in uF, and R is in kOhm

# On the ‘scope

A calculation using measured values of

R = 55k and

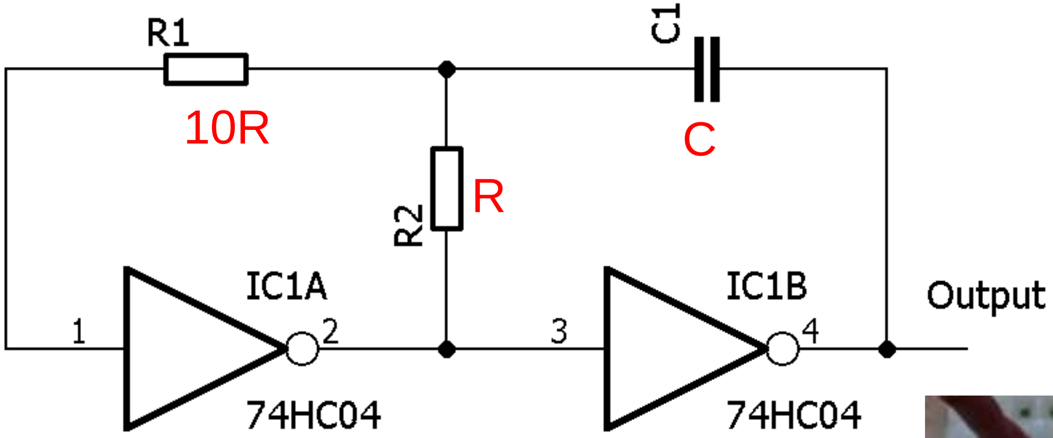
C = 0.105uF

gives a frequency of 78.7 Hz.

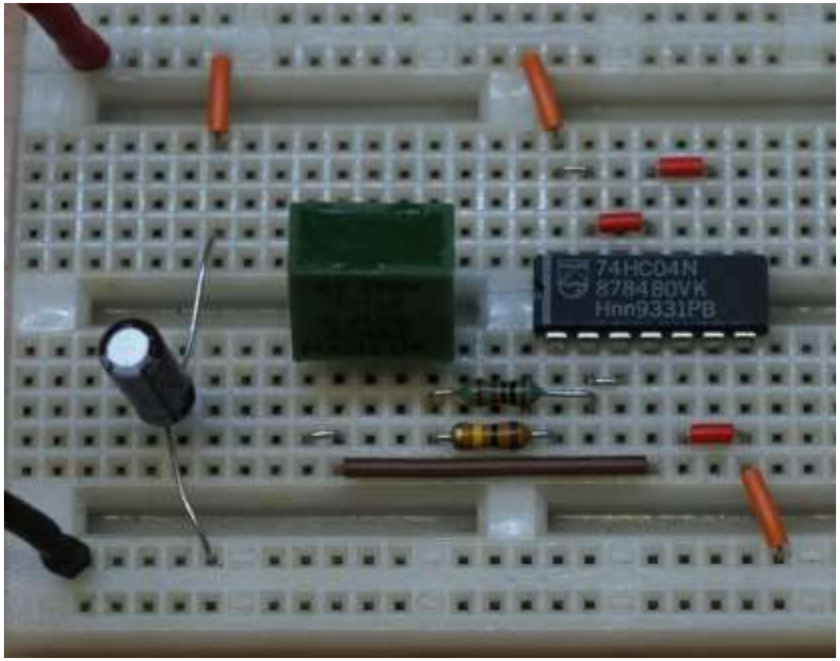
The measured frequency was 78.04 Hz.

The output waveform is a square wave rather than a sine wave.

# CMOS Inverter Oscillator



Another square wave circuit, using a digital logic IC.



Output Frequency $F = \frac{10\text{^}3}{2.2 \times C \times R}$ kHz

Where C is in uF, and R is in kOhm

A calculation using measured values of
R = 9.95k and
C = 0.091uF
gives a frequency of 503 Hz.

The measured frequency was 493 Hz.

# On the ‘Scope

A nice square wave …

… or is it?

# … and again…

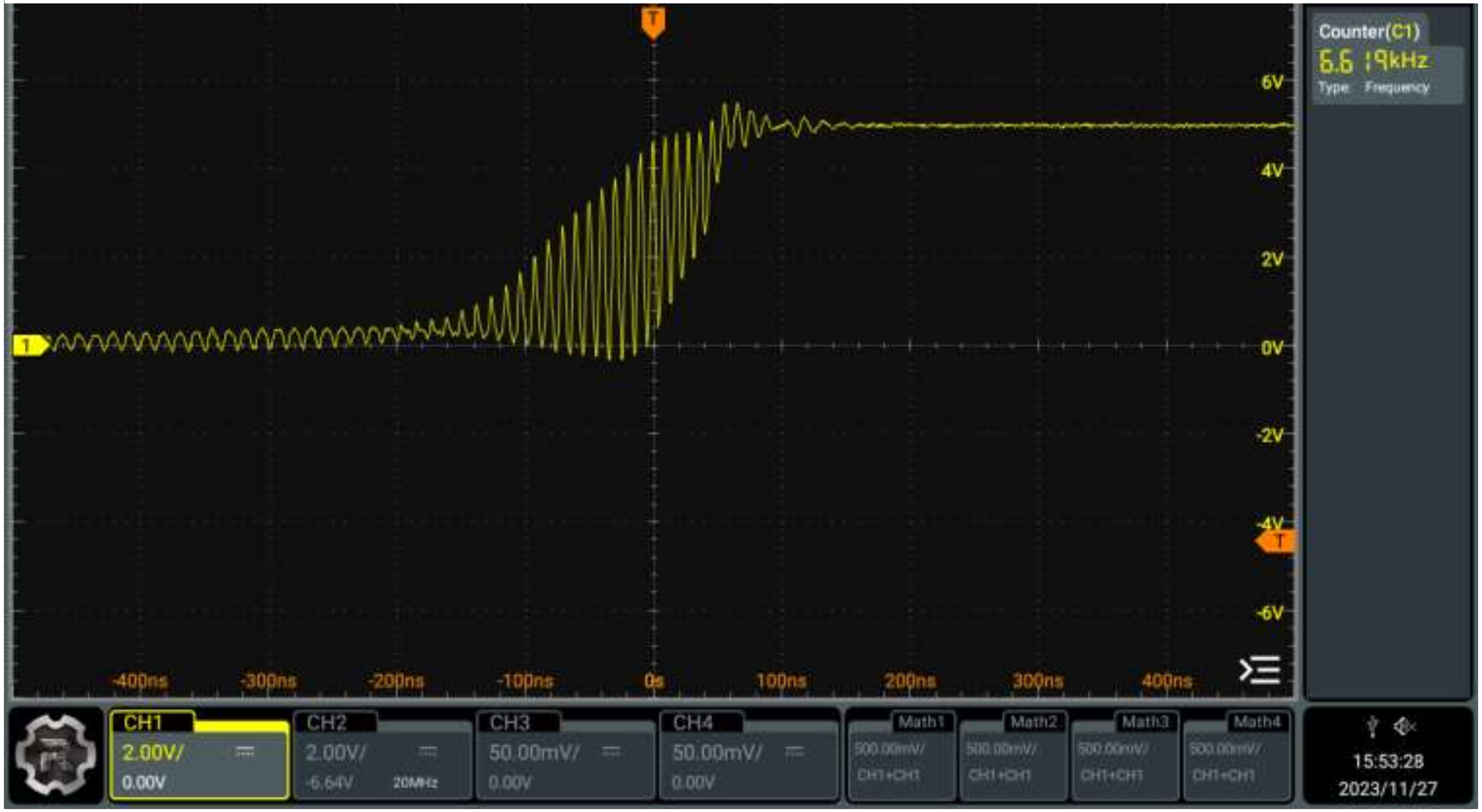
Speed up the timebase and look at the rising edge…

… looks OK with the bandwidth limited to 20MHz

# … and finally!

…But use the full 400MHz bandwidth of the scope to see the ringing on the rising (and falling edges) of the signal.

(Probably due to stray inductance in the breadboard)



CH1 2.00V/ 0.00V

CH2 2.00V/ -6.64V 20MHz

CH3 50.00mV/ 0.00V

CH4 50.00mV/ 0.00V

Math1 500.00mV/ CH1+CH1

Math2 500.00mV/ CH1+CH1

Math3 500.00mV/ CH1+CH1

Math4 500.00mV/ CH1+CH1

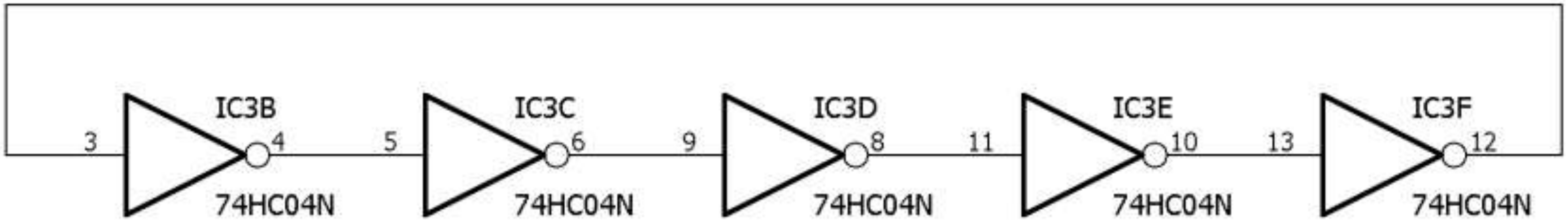
Leaves something to be desired.

# The Ring Oscillator (Bonus Content*)

* I had another 74HC04 lying on the bench.

Uses nothing but an odd number of logic inverters (NOT Gates).

The output can be from any inverter output/input, they are all the same.

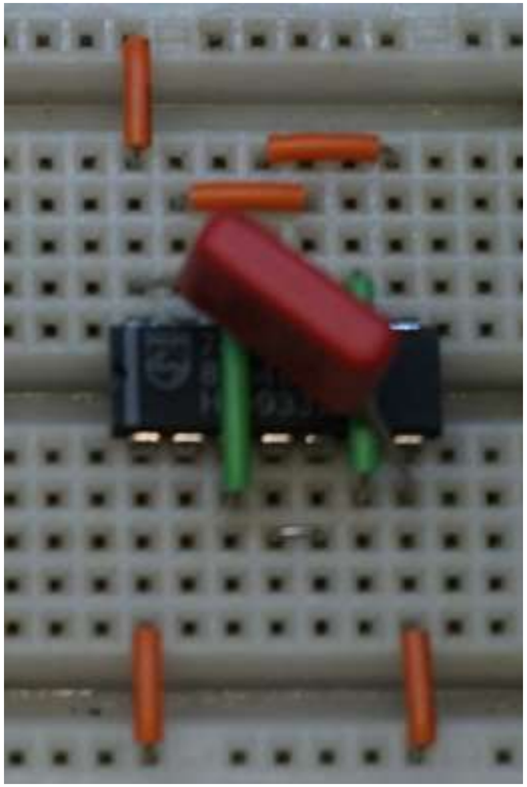


The oscillation frequency is given by the expression $F = \frac{1}{2tn}$
Where *t* is the propagation delay through a gate and *n* is the number of gates.
The NXP datasheet for the 74HC04 gives the propagation delay as 7nS (typical)

Calculating for five gates gives F = 14.28 MHz.
The measured frequency of the demo circuit was 17.48 MHz.
Faster gates with propagation delay less than typical.

The red capacitor is for supply decoupling.

On the ‘scope, a 17MHz square (ish) waveform is not exactly the output of an audio oscillator.



Post script.
The propagation delay of 74HC04 was measured at approx. 5.8nS per gate. This gives a calculated frequency of 16.66 MHz.
The measured frequency during the delay measurement was 16.52 MHz (Two scope probes attached to the circuit).

# The End