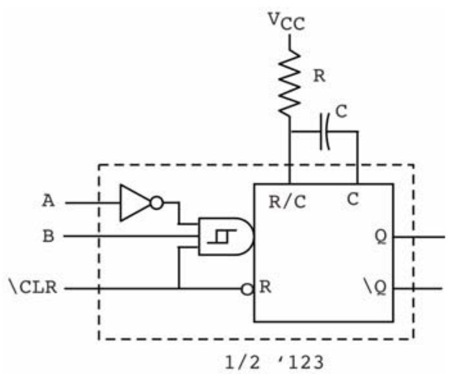
TIMING CIRCUITS

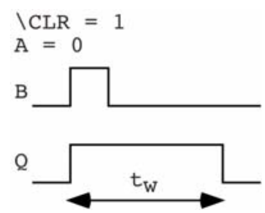
- one-shots
- timer 555
- counting with FF
- 555 oscillator
- relaxation oscillator
- VCO

MONOSTABLE MULTIVIBRATOR (ONE-SHOTS)

- Generates a fixed length output pulse after receiving a trigger signal. The pulse length is determined by external RC network



$\overline{CLR}$	A	B	Q	$\overline{Q}$
0	X	X	0	1
1	0	↑	⊓	⊔
1	↓	1	⊓	⊔
↑	0	1	⊓	⊔



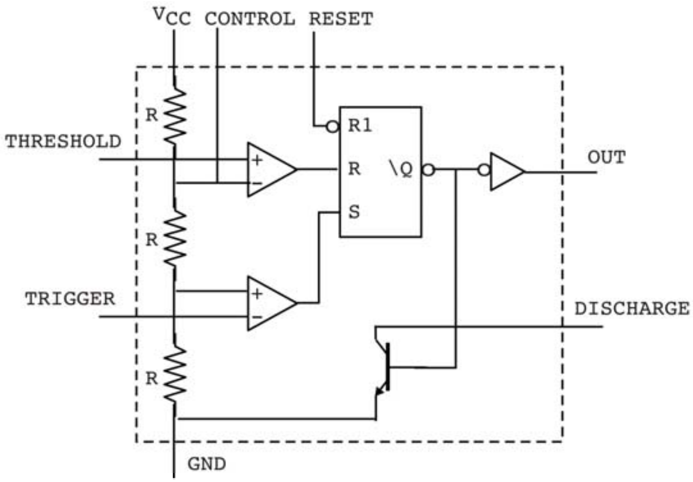
$$t_w[ns] = 0.28 R_x[k\Omega] C_x[pF]\left(1 + \frac{0.7}{R_x[k\Omega]}\right)$$ for $C_x > 1000$pF

- 74123
- 4538: CMOS
- 74121: 74221 dual '121
- 74423

One-shot Parameters
- input gating
- retriggerability
- resettability
- pulse width

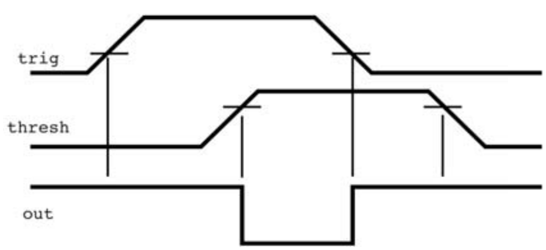
TIMER 555

General purpose variable timing device:
- monostable multivibrator (pulse generator)
- astable multivibrator (oscillator)
- ramp generator
- pulse width modulation
- pulse position modulation



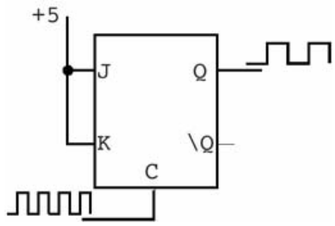
Function Table

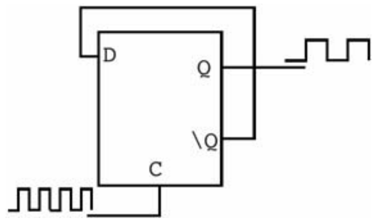
reset	trigger	threshold	OUT	discharge
L	X	X	L	on
H	$< \frac{1}{3} V_{CC}$	X	H	off
H	$> \frac{1}{3} V_{CC}$	$> \frac{2}{3} V_{CC}$	L	on
H	$> \frac{1}{3} V_{CC}$	$< \frac{2}{3} V_{CC}$	n.c.	n.c.



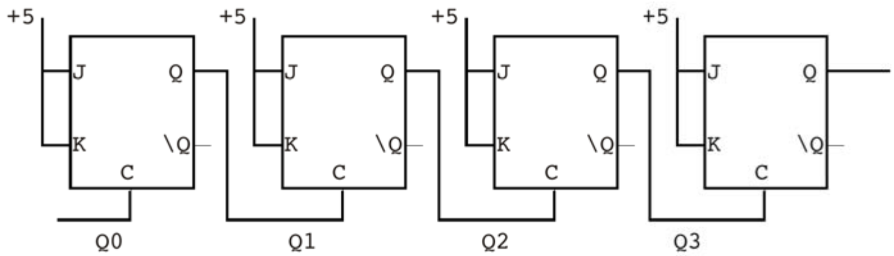
COUNTING WITH FF

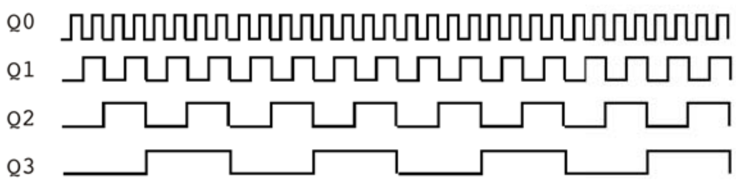
Divide-by-2





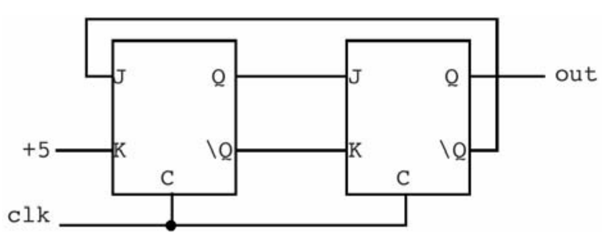
Divide-by-2^N: Binary Ripple Counter

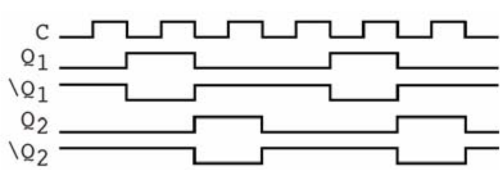


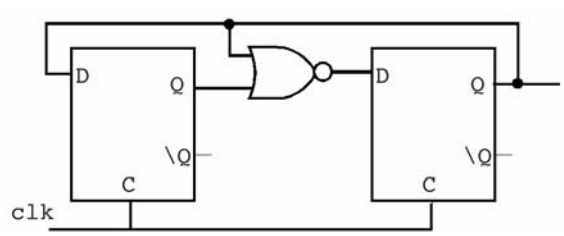


Q_3	Q_2	Q_1	Q_0
0	0	0	0
0	0	0	1
0	0	1	0
0	0	1	1
0	1	0	0
0	1	0	1
0	1	1	0
	…		
1	1	1	0
1	1	1	1
0	0	0	0
0	0	0	1

Dived-by-Three Synchronous Counter







Pulse Train Synchronizer

- using SR FF and D register

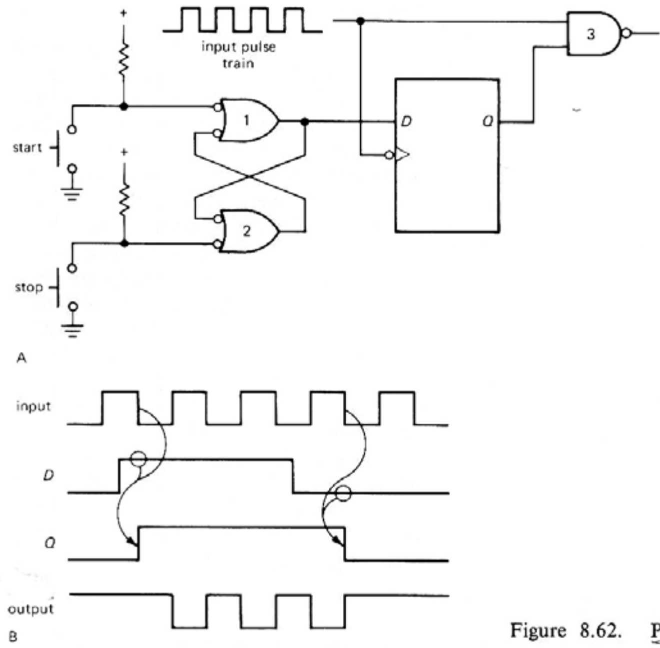


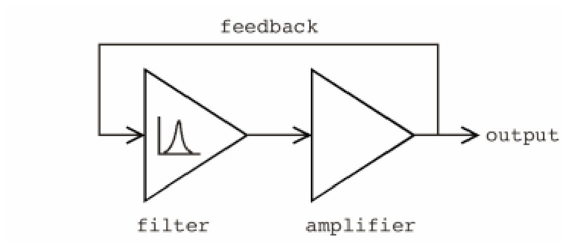
Figure 8.62. Pulse-train synchronizer.

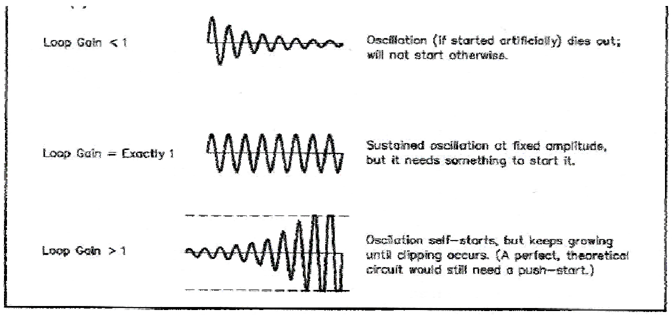
Counters

- binary counter: 74393
- BCD counter: modulo-10 counter: 74390
- modulo-n counter
- cascading

- ripple counter
- synchronous counter
  - 74160-163: 4-bit synchronous
  - 74590,592: 8-bit synchronous
- up/down counter: 74191, 74193, 74569, 74579
- load & clear
- counter + latch: latched data can be displayed while counting continues
- three-state output: 74779
- 74C925-928: counter + latch + 7-seg decoder, driver
- TIL306/7: counter with display
- Intersil 7216: 8-bit 10MHz universal counter, w. dispaly

OSCILLATORS





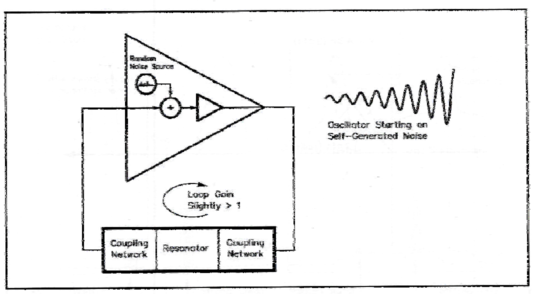
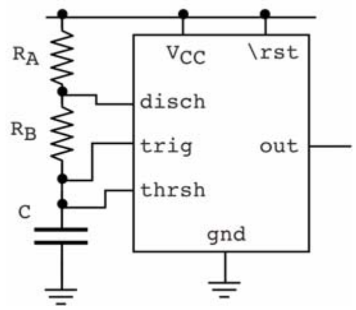


Fig 14.5 — An oscillator with noise. Real-world amplifiers, no matter how quiet, generate some internal noise; this allows real-world oscillators to self-start.

OSCILLATOR WITH 555



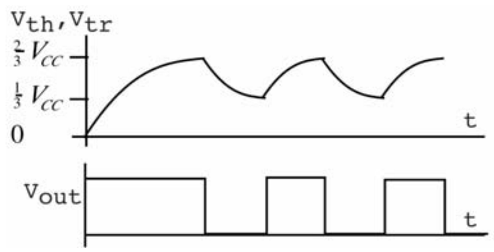
$Q = 0 \quad V_{trig} = 0 \quad \therefore trigger \quad \Rightarrow$ OUT = Hi

$V_{tr} = V_{th} = 0 \rightarrow \frac{2}{3}V_{CC} \quad \Rightarrow$ OUT = Lo

Disch = on

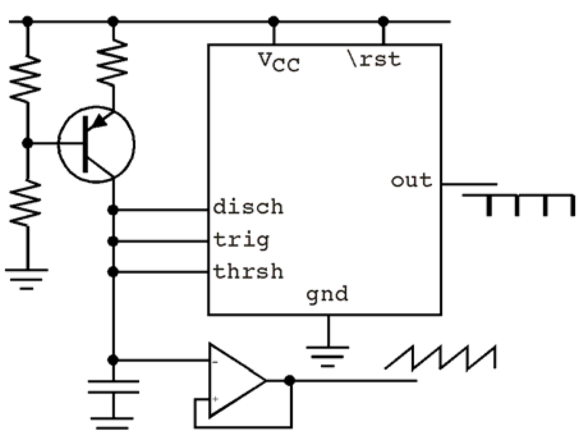
$V_{tr} = V_{th} = \frac{2}{3}V_{CC} \rightarrow \frac{1}{3}V_{CC} \quad \Rightarrow$ OUT = Hi

Charge through $R_A + R_B$; discharge through R_B



- $T = 0.693(R_A + 2R_B)C$
- duty cycle: $\frac{R_A + R_B}{R_A + 2R_B} \geq 50\%$

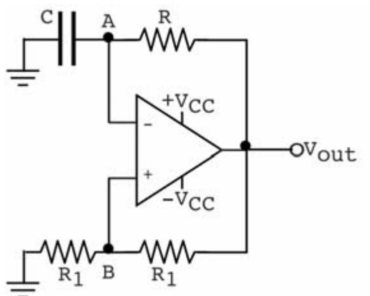
Sawtooth Generator



RELAXATION OSCILLATOR

OpAmp circuit with saturation

Saturation:
$$\begin{aligned} &If\ \ V_+ > V_- \quad \Rightarrow \quad V_{out} = +V_{CC} \\ &If\ \ V_+ < V_- \quad \Rightarrow \quad V_{out} = -V_{CC} \end{aligned}$$



$V_B = \frac{1}{2} V_{out}$ always.

If $V_{out} = +V_{CC}$ initially:

Capacitor charges toward +V_{CC}

$V_B = \frac{1}{2} V_{CC}$

When V_A reaches $V_{CC}/2$ $\Rightarrow$ $V_- > V_+$ $\Rightarrow$ $V_{out} = -V_{CC}$

Capacitor discharges toward -V_{CC}

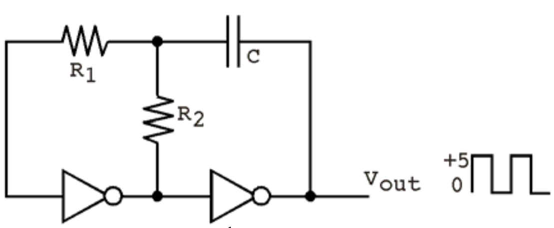
$V_B = -\frac{1}{2} V_{CC}$

When V_A reaches -$V_{CC}/2$ $\Rightarrow$ $V_- < V_+$ $\Rightarrow$ $V_{out} = +V_{CC}$

Repeat from beginning ↵

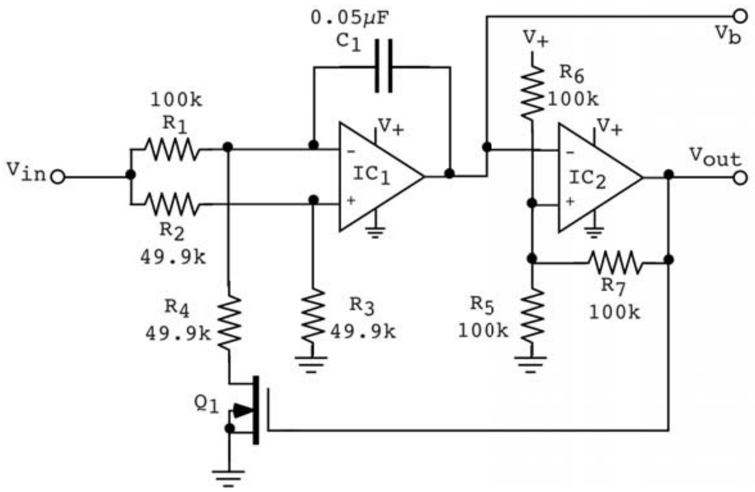
- $f = \dfrac{0.45}{RC}$

CMOS Relaxation Oscillator



- $R_1 << R_2;$ $\qquad f \approx \dfrac{1}{RC}$
- very low noise

VOLTAGE-CONTROLLED OSCILLATOR: VCO



IC$_1$: Integrator

If Q_1 is not conducting (V_{out} = 0)

$$V_a = V_{in}\frac{R_2}{R_2+R_3} = 0.5V_{in}$$

$$I_1 = \frac{V_{in}-V_a}{R_1} = \frac{0.5V_{in}}{100k} = (5\mu A/V)V_{in}$$

$$V_b = V_a - \frac{I_1 t}{C_1} = 0.5V_{in} - \frac{5\mu A/V}{0.05\mu F}V_{in}t = 0.5V_{in} - (100)V_{in}t$$

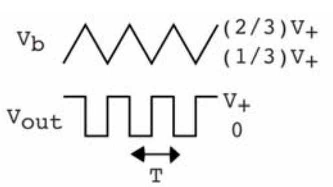
If Q_1 is conducting ($V_{out} = V_+$)

$$I_1'' = \frac{V_a}{R_4} = \frac{0.5V_{in}}{49.9k} = 2I_1$$

$$I_1' = I_1'' - I_1 = I_1$$

$$V_b = V_a + \frac{I_1 t}{C_1} = 0.5V_{in} + (100)V_{in}t$$

IC$_2$: Schmitt Trigger



$$T = \frac{2}{3}\frac{V_+}{100V_{in}}; \qquad f = 150\frac{V_{in}}{V_+}[Hz]$$

$$0 \le V_{in} \le 2(V_+ - 1.5V)$$

- VCO's can also be made from 555 timers.

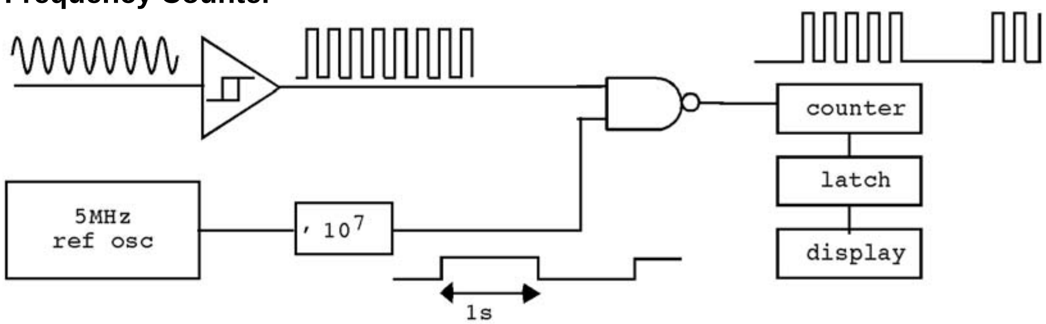
Function Generator

- VCO + wave shaping
- integrate square wave > triagular wave
- integrate triangular wave > low pass filter > good approx. of sine wave

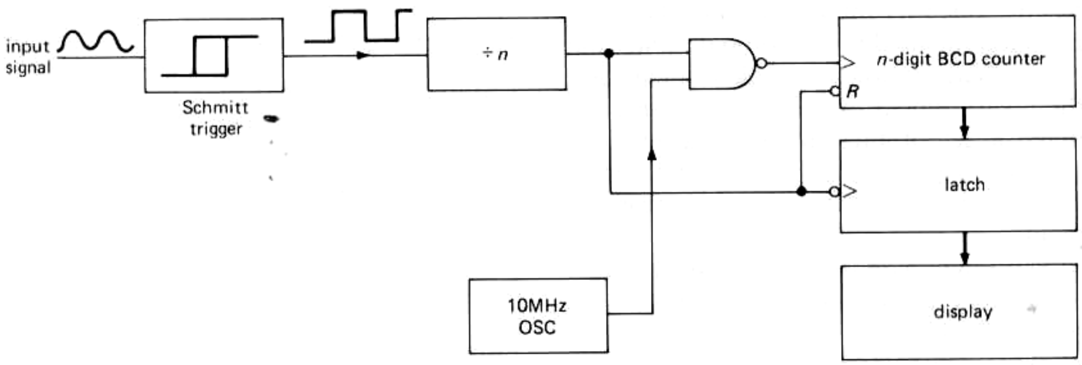
VCO ICs
- 8038, 2206
- 74LS624-9: 20MHz
- 1648: 200MHz
- VFC, voltage-to-frequency converters: LM331, AD650
- PLL: VCO+phase detector: 4046, 74HC4046

FREQUENCY MEASUREMENTS

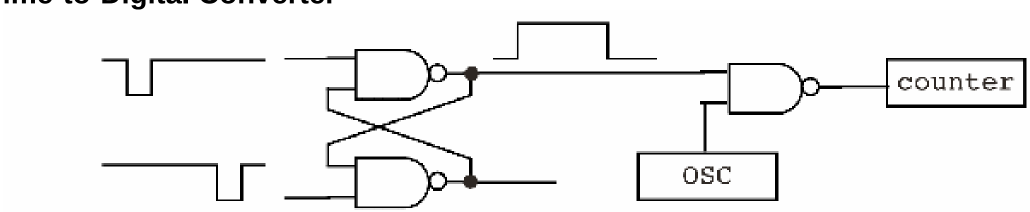
Digital Frequency Counter



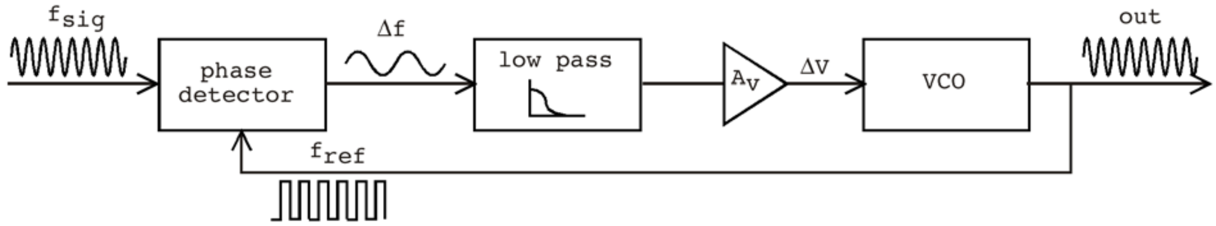
Period (Reciprocal) Counting



TDC: Time-to-Digital Converter



PLL: PHASE-LOCKED LOOP



Type I Digital Phase Detector