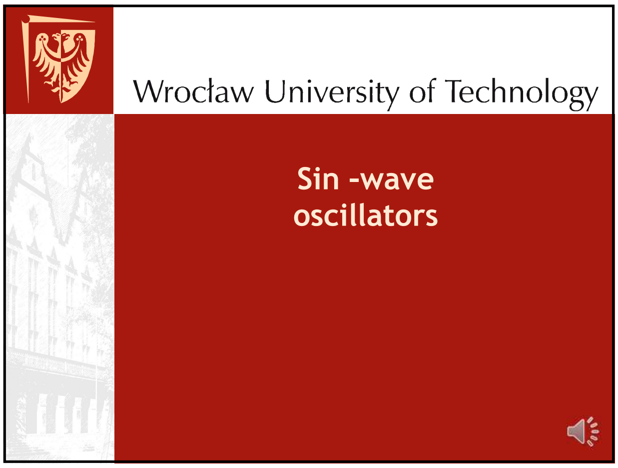

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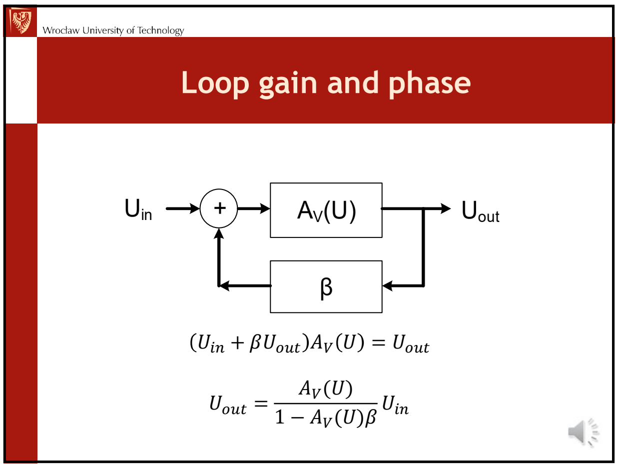
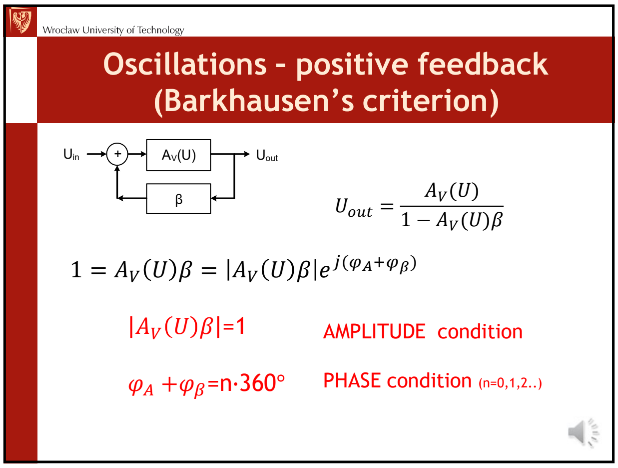
Sin -wave oscillators



Loop gain and phase

$$(U_{in} + \beta U_{out})A_V(U) = U_{out}$$

$$U_{out} = \frac{A_V(U)}{1 - A_V(U)\beta} U_{in}$$



Oscillations - positive feedback (Barkhausen’s criterion)

$$U_{out} = \frac{A_V(U)}{1 - A_V(U)\beta}$$

$$1 = A_V(U)\beta = |A_V(U)\beta| e^{j(\varphi_A + \varphi_\beta)}$$

$|A_V(U)\beta|=1$ AMPLITUDE condition

$\varphi_A + \varphi_\beta = n \cdot 360°$ PHASE condition (n=0,1,2..)

Phase and Amplitude conditions

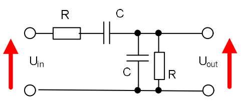
$|A_V(U)\beta|=1$

usually $|A_V(U)\beta| > 1$
U increases → $A_V(U)$ decreases
so:
amplitude of oscillation is limited

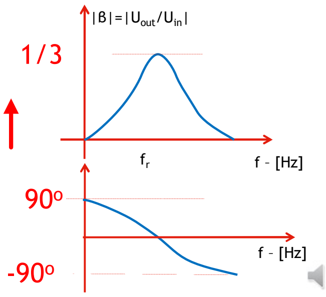
$\varphi_A + \varphi_\beta(f) = n \cdot 360$

so:
frequency of oscillation is adjusted

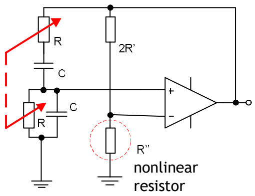
Wien-bridge oscilator



$$f_r = \frac{1}{2\pi RC}$$

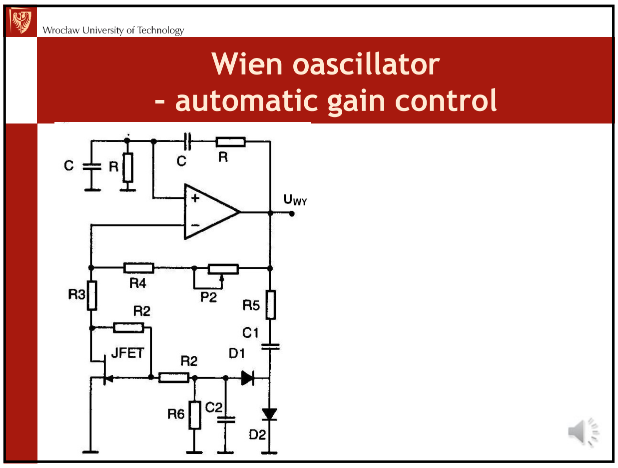


Wien oscillator



$$f_r = \frac{1}{2\pi RC}$$

$$|A_V(U)| = \frac{2R'}{R''(U)} + 1 \approx 3$$



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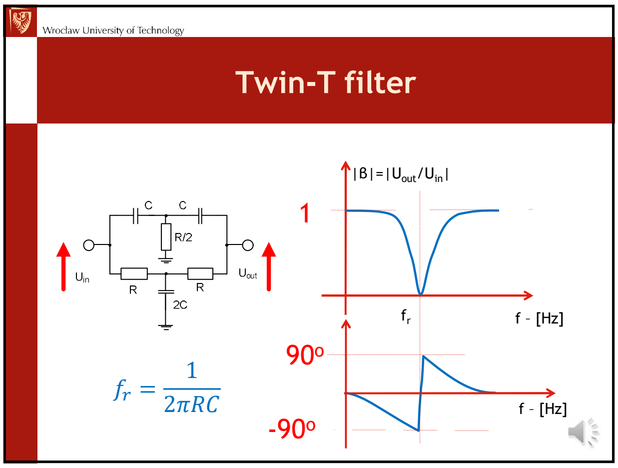
Wien oascillator - automatic gain control



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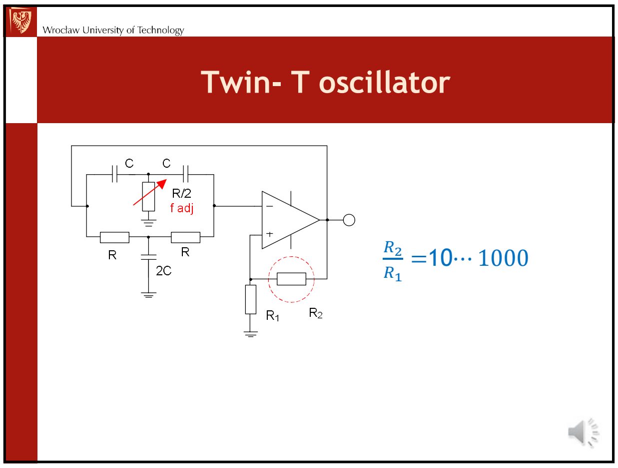
Twin-T filter

$$f_r = \frac{1}{2\pi RC}$$



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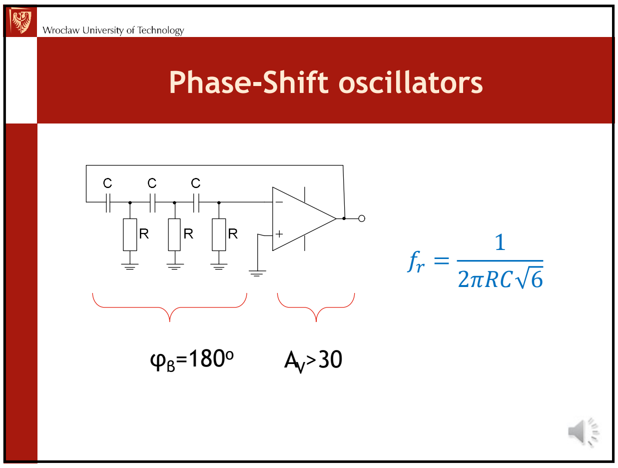
Twin- T oscillator

$$\frac{R_2}{R_1} = 10 \cdots 1000$$



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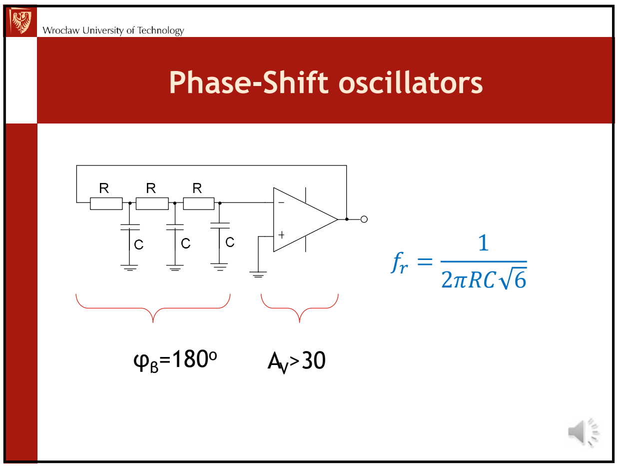
Phase-Shift oscillators

$$f_r = \frac{1}{2\pi RC\sqrt{6}}$$

φ_B=180° A_V>30



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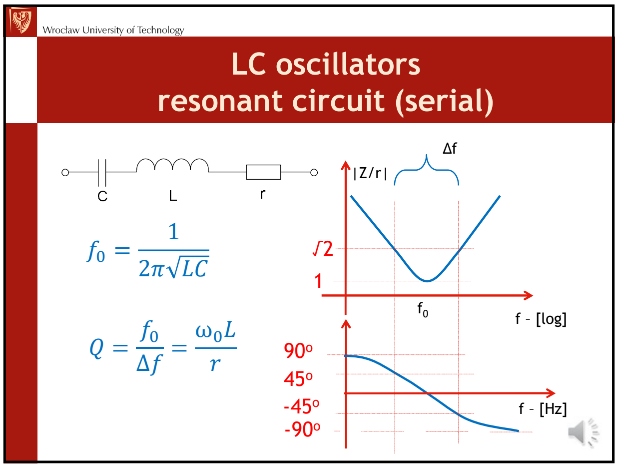
Phase-Shift oscillators

$$f_r = \frac{1}{2\pi RC\sqrt{6}}$$

φ_B=180° A_V>30



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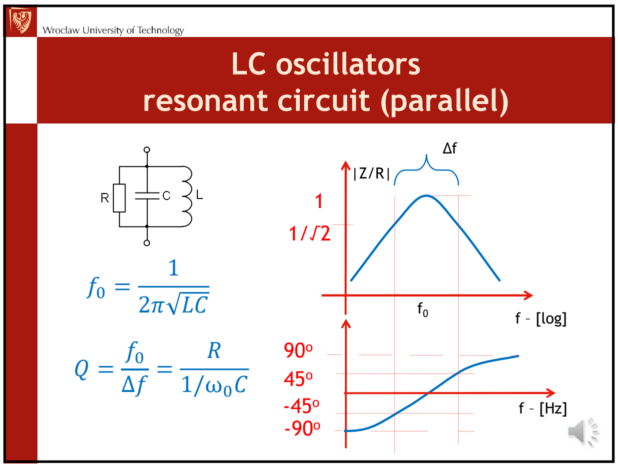
LC oscillators
resonant circuit (serial)

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

$$Q = \frac{f_0}{\Delta f} = \frac{\omega_0 L}{r}$$



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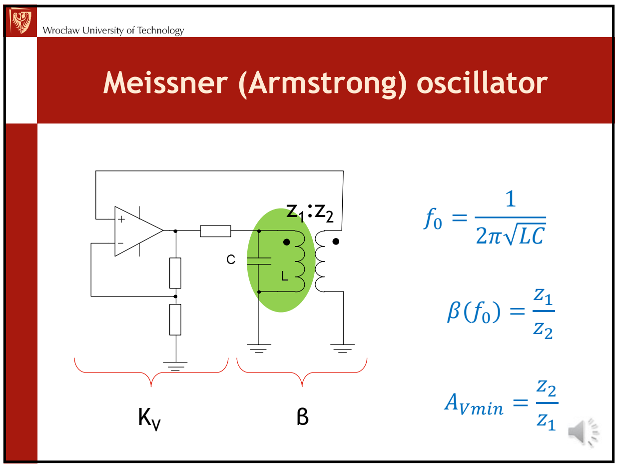
LC oscillators resonant circuit (parallel)

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

$$Q = \frac{f_0}{\Delta f} = \frac{R}{1/\omega_0 C}$$



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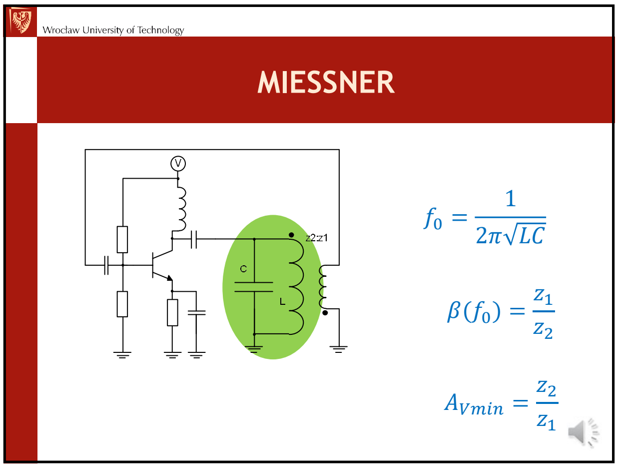
Meissner (Armstrong) oscillator

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

$$\beta(f_0) = \frac{z_1}{z_2}$$

$$A_{Vmin} = \frac{z_2}{z_1}$$



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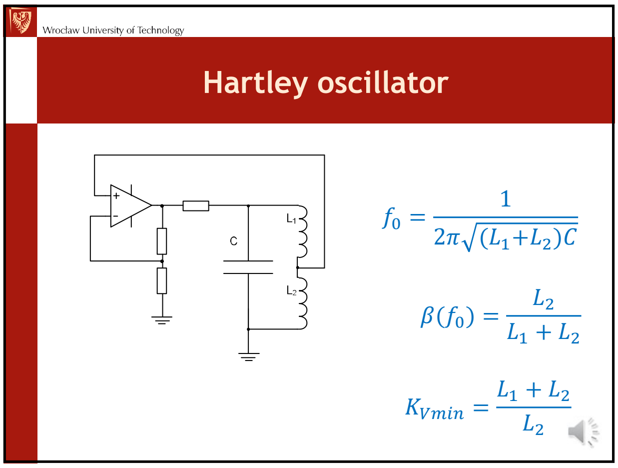
MIESSNER

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

$$\beta(f_0) = \frac{z_1}{z_2}$$

$$A_{Vmin} = \frac{z_2}{z_1}$$



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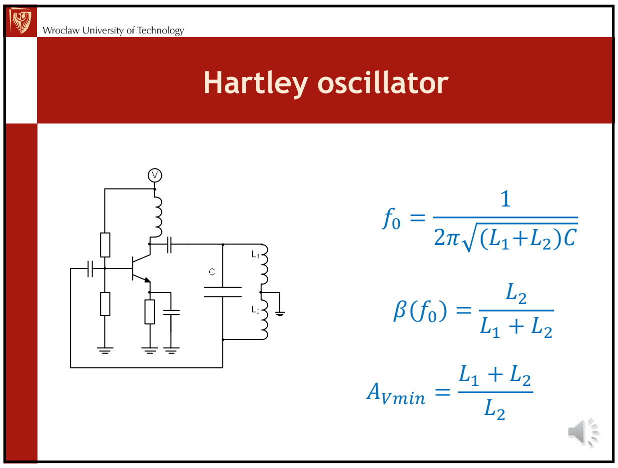
Hartley oscillator

$$f_0 = \frac{1}{2\pi\sqrt{(L_1+L_2)C}}$$

$$\beta(f_0) = \frac{L_2}{L_1 + L_2}$$

$$K_{Vmin} = \frac{L_1 + L_2}{L_2}$$



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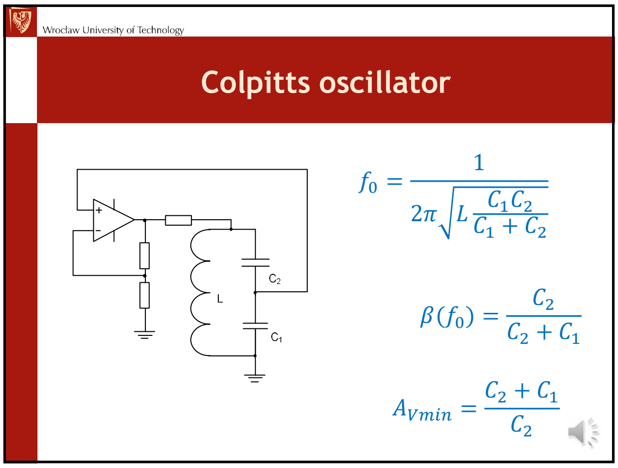
Hartley oscillator

$$f_0 = \frac{1}{2\pi\sqrt{(L_1+L_2)C}}$$

$$\beta(f_0) = \frac{L_2}{L_1 + L_2}$$

$$A_{Vmin} = \frac{L_1 + L_2}{L_2}$$



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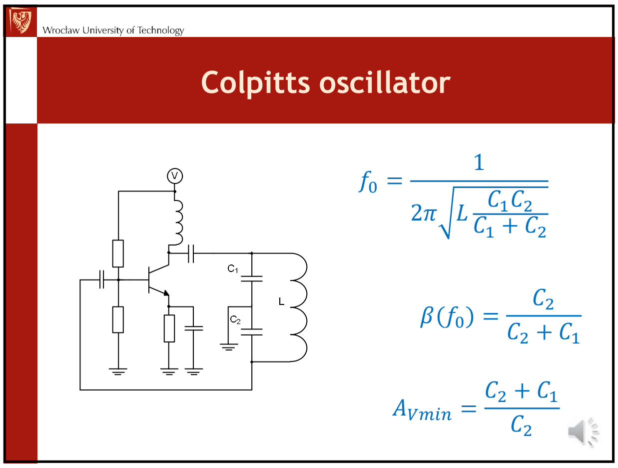
Colpitts oscillator

$$f_0 = \frac{1}{2\pi\sqrt{L\frac{C_1 C_2}{C_1 + C_2}}}$$

$$\beta(f_0) = \frac{C_2}{C_2 + C_1}$$

$$A_{Vmin} = \frac{C_2 + C_1}{C_2}$$



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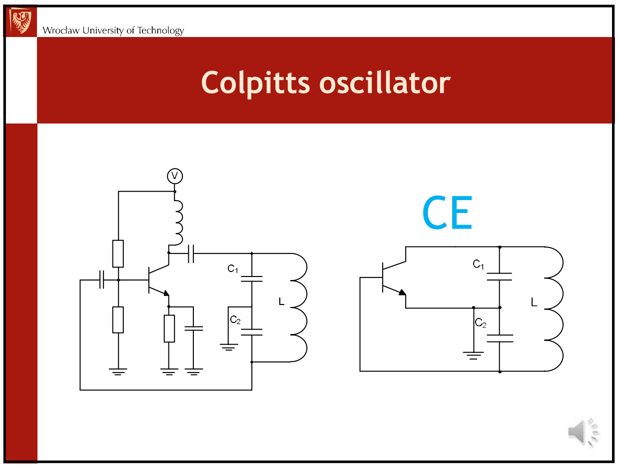
Colpitts oscillator

$$f_0 = \frac{1}{2\pi\sqrt{L\frac{C_1C_2}{C_1+C_2}}}$$

$$\beta(f_0) = \frac{C_2}{C_2+C_1}$$

$$A_{Vmin} = \frac{C_2+C_1}{C_2}$$



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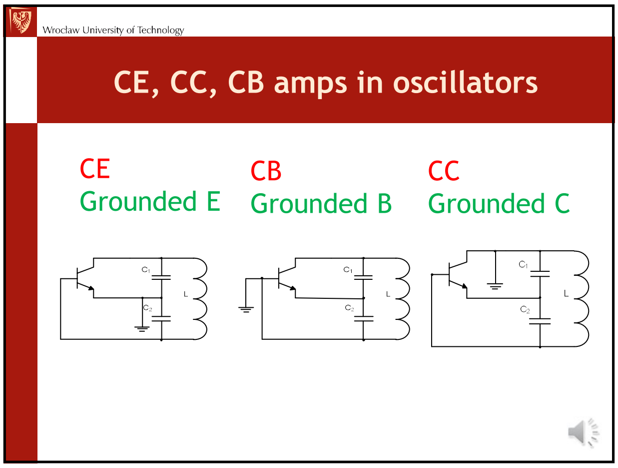
Colpitts oscillator

CE



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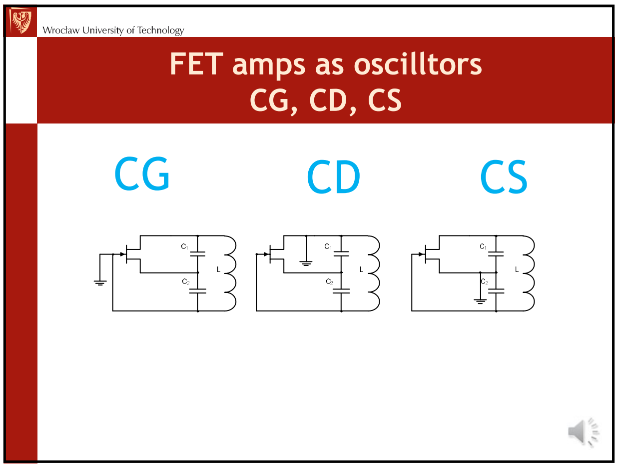
CE, CC, CB amps in oscillators

CE
Grounded E

CB
Grounded B

CC
Grounded C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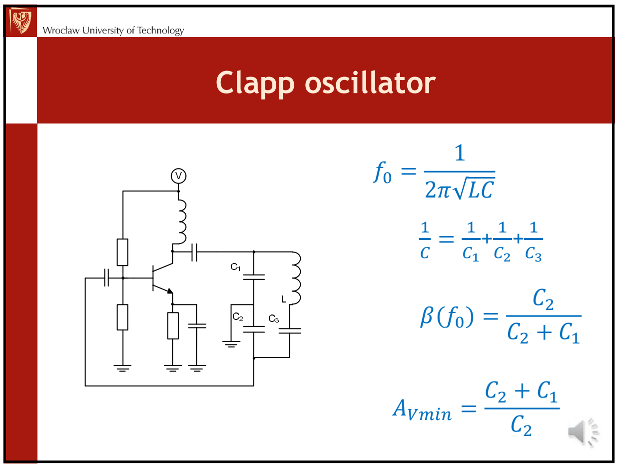
FET amps as oscilltors
CG, CD, CS

CG CD CS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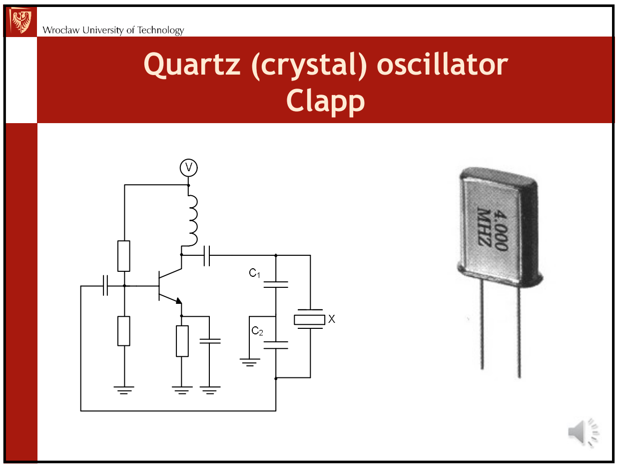
Clapp oscillator

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$$\beta(f_0) = \frac{C_2}{C_2 + C_1}$$

$$A_{Vmin} = \frac{C_2 + C_1}{C_2}$$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Quartz (crystal) oscillator
Clapp

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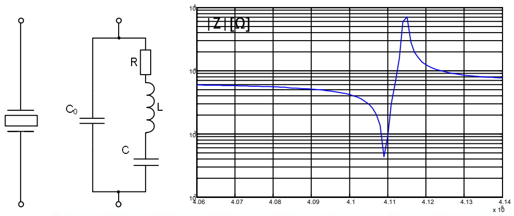
Crystal equivalent circuit



f [Hz]	100 k	500 k	1 M	4 M	10 M	20 M	60 M	120 M
R [Ω]	400	500	250	100	20	10	30	50
L [H]	93,8	20,3	3,62	0,100	0,0169	0,0042	0,0035	0,00293
C [pF]	0,027	0,005	0,007	0,015	0,015	0,015	0,002	0,0006
C_0 [pF]	6	6	5	5	3,5	3	5	4

Q=25e3

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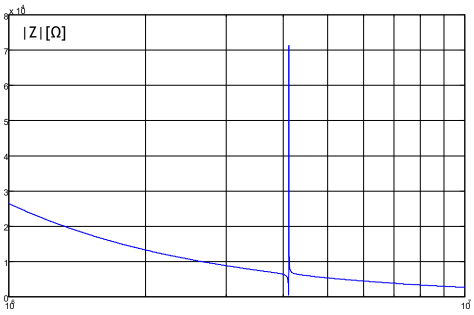
|Z(f)|



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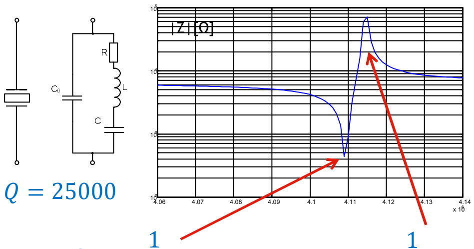
Series and Parallel resonance of a crystal resonator of 4MHz



$Q = 25000$

$$f_s = \frac{1}{2\pi\sqrt{LC}} \qquad f_p = \frac{1}{2\pi\sqrt{L\frac{CC_0}{C+C_0}}}$$

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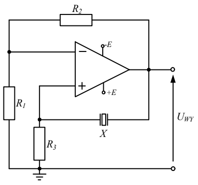
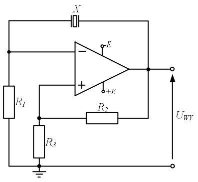


fs - |z|=min



fp - |z|=max

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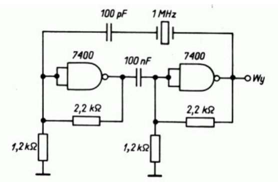
series resonans



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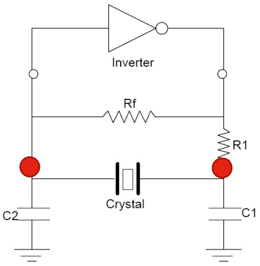
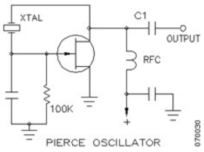
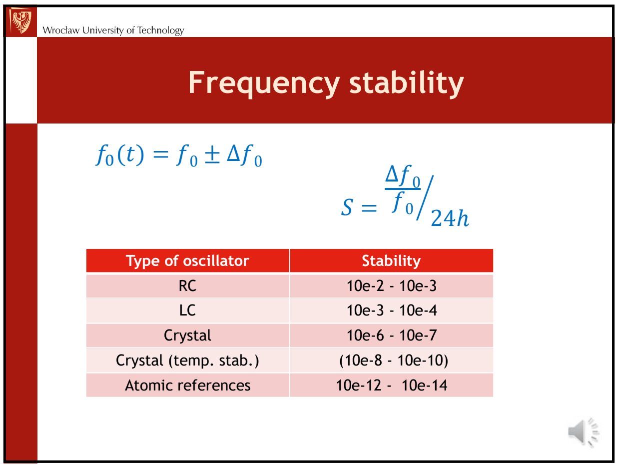
Pierce oscillator – an example







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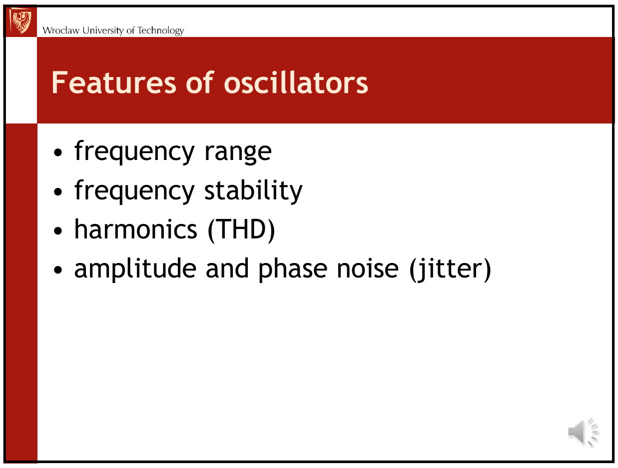
Frequency stability

$$f_0(t) = f_0 \pm \Delta f_0$$

$$S = \frac{\Delta f_0}{f_0} \Big/ 24h$$

Type of oscillator	Stability
RC	10e-2 - 10e-3
LC	10e-3 - 10e-4
Crystal	10e-6 - 10e-7
Crystal (temp. stab.)	(10e-8 - 10e-10)
Atomic references	10e-12 - 10e-14



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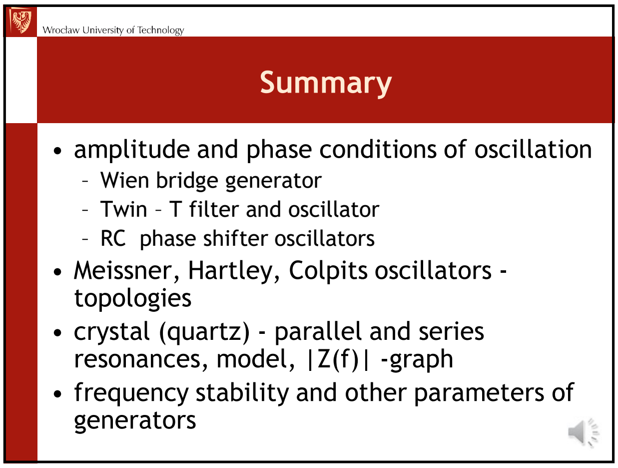
Features of oscillators

- frequency range
- frequency stability
- harmonics (THD)
- amplitude and phase noise (jitter)



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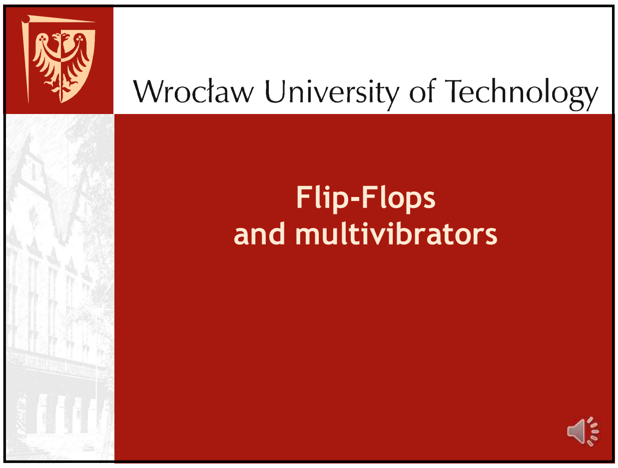
Summary

- amplitude and phase conditions of oscillation
  - Wien bridge generator
  - Twin - T filter and oscillator
  - RC phase shifter oscillators
- Meissner, Hartley, Colpits oscillators - topologies
- crystal (quartz) - parallel and series resonances, model, |Z(f)| -graph
- frequency stability and other parameters of generators



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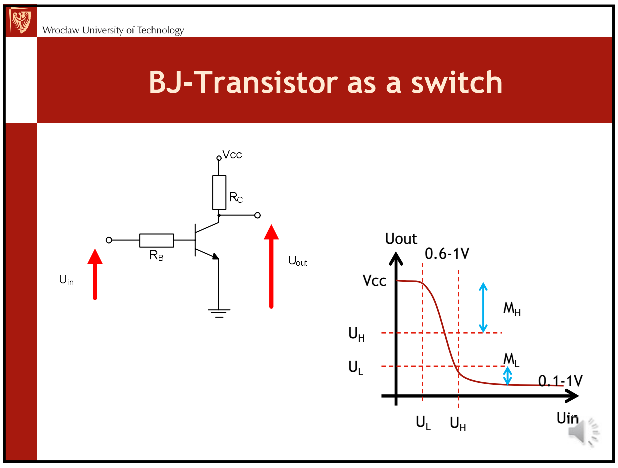
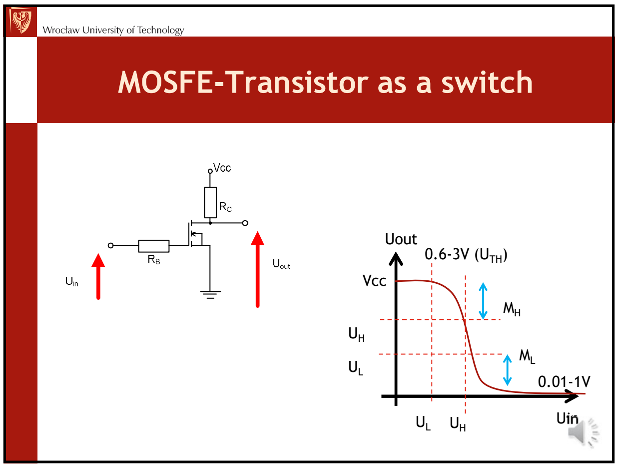
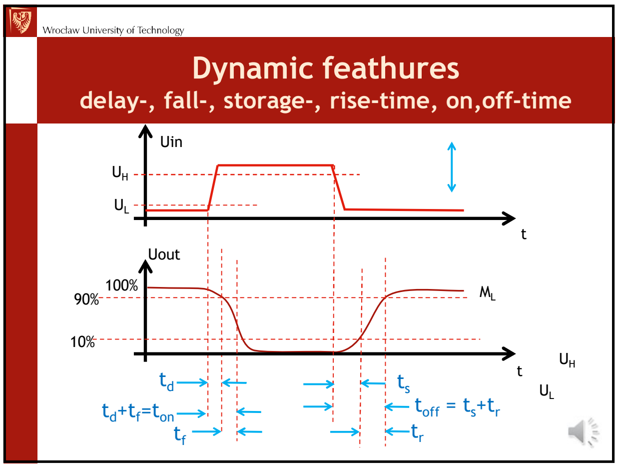
Flip-Flops and multivibrators



BJ-Transistor as a switch



MOSFE-Transistor as a switch



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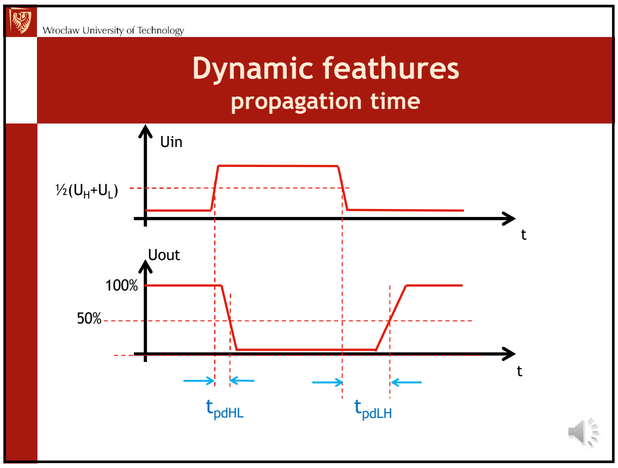
Dynamic feathures

delay-, fall-, storage-, rise-time, on,off-time



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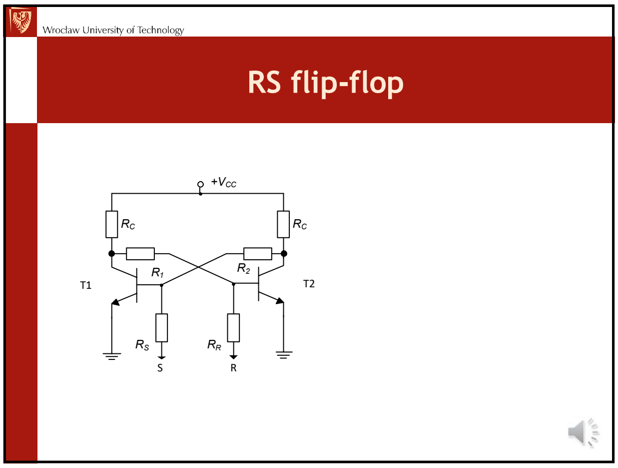
Dynamic feathures

propagation time



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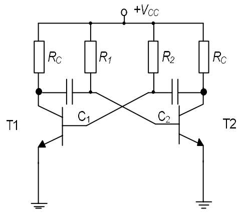
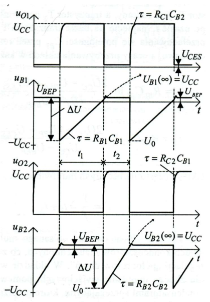
RS flip-flop

Astable Flip-Flop



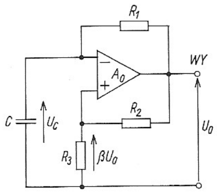


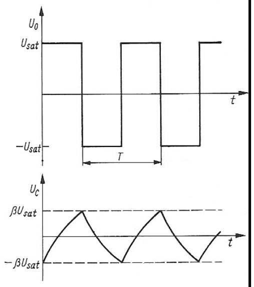
$t_1 \approx 0.7R_1C_1$

$t_2 \approx 0.7R_2C_2$

$$R_C \ll R_1, R_2 \ll \beta R_C$$

OpAmp(Comparator) Flip-Flop

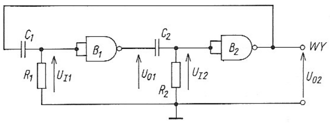


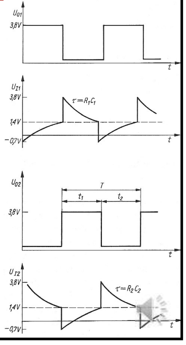


$$T = 2R_1C\ln\frac{1+\beta}{1-\beta}$$

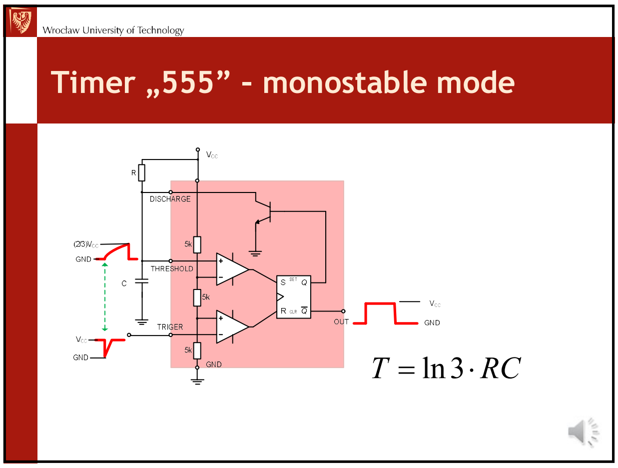
$$\beta = \frac{R_3}{R_2 + R_3}$$

Astable Flip-Flop with NAND Gate





$$f = \frac{1}{t_1 + t_2} = \frac{1}{R_1C_1 + R_2C_2}$$



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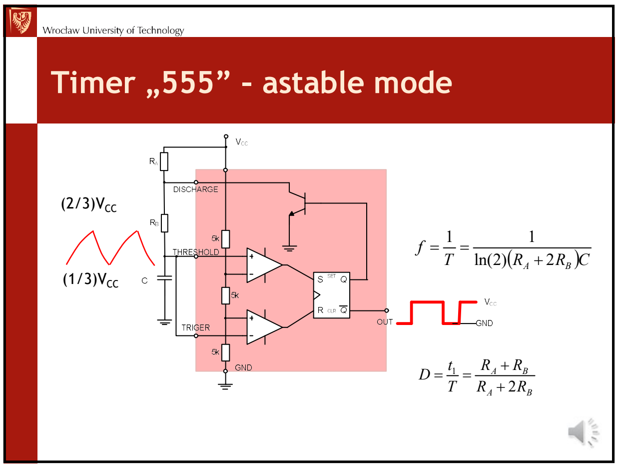
Timer „555" - monostable mode

$$T = \ln 3 \cdot RC$$



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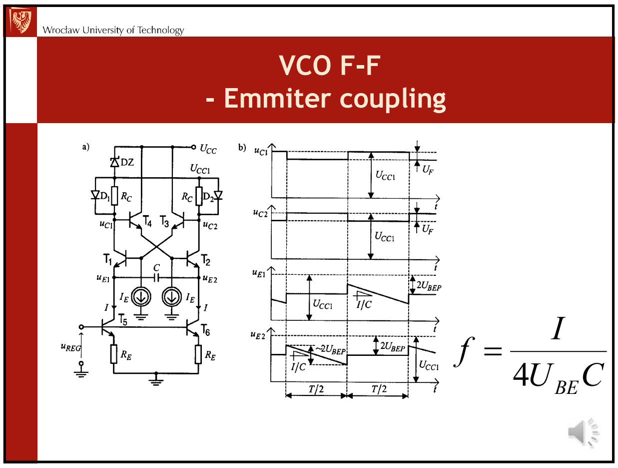
Timer „555" - astable mode

$$f = \frac{1}{T} = \frac{1}{\ln(2)(R_A + 2R_B)C}$$

$$D = \frac{t_1}{T} = \frac{R_A + R_B}{R_A + 2R_B}$$



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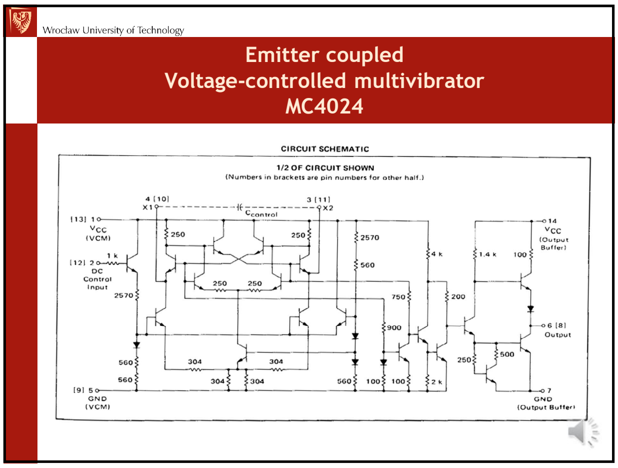
VCO F-F
- Emmiter coupling

$$f = \frac{I}{4U_{BE}C}$$



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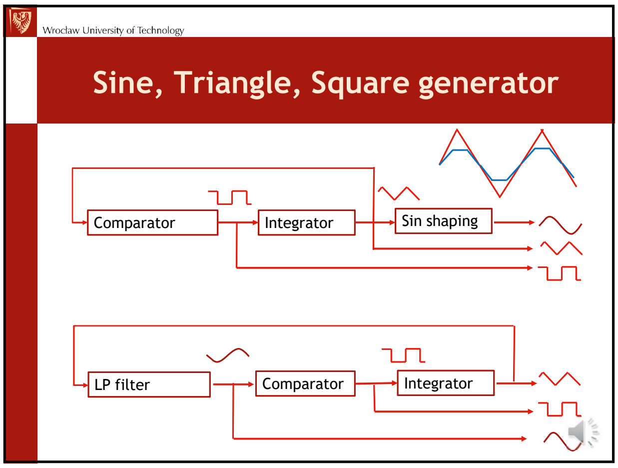
Emitter coupled
Voltage-controlled multivibrator
MC4024

CIRCUIT SCHEMATIC

1/2 OF CIRCUIT SHOWN

(Numbers in brackets are pin numbers for other half.)



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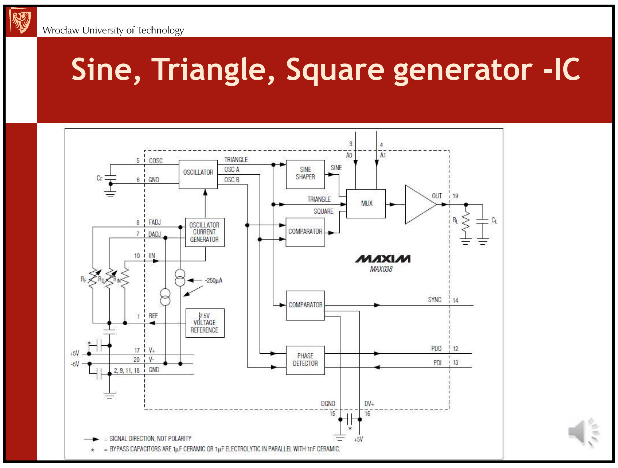
Sine, Triangle, Square generator



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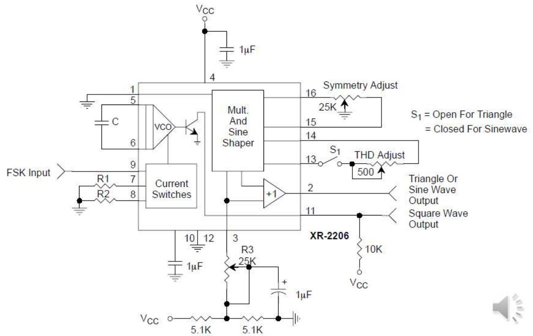
Sine, Triangle, Square generator -IC

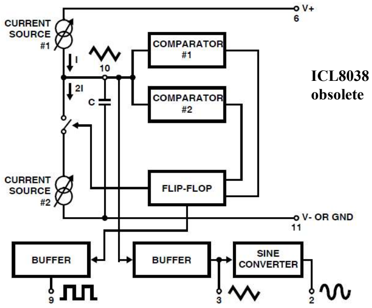
→ = SIGNAL DIRECTION, NOT POLARITY

* = BYPASS CAPACITORS ARE 1µF CERAMIC OR 1µF ELECTROLYTIC IN PARALLEL WITH 1nF CERAMIC.

Sine, Triangle, Square generator -IC

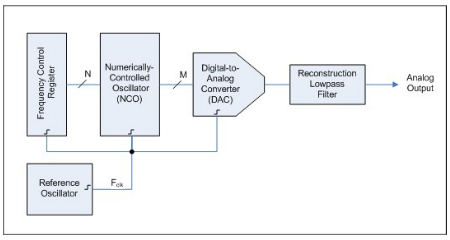


Sine, Triangle, Square generator -IC

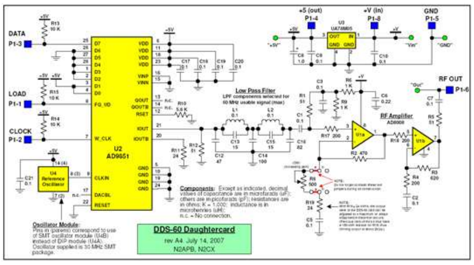


ICL8038
obsolete

DDS - *Direct Digital Synthesis*



DDS - *Direct Digital Synthesis*



Summary

- Phase and amplitude conditions of oscillations
- Flip-Flop as a-stable and mono-stable
- Timer 555
- Function generator
- DDS generator