Generators and laboratory power sources

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Generators

- Sources of various test signals (stimulus) for testing, maintaining and development electronic circuits and systems
- Classification
  - Harmonic (Low frequency sinewave)
  - Function (different shape waveforms in LF band)
  - Arbitrary (the waveform shape is programmable)
  - Pulse (square pulses with setable parameters)
  - High frequency (includes different modulations)
    - Radiofrequency (up to a few GHz)
    - Microwave (above tens of GHz)
  - Other special types, e.g., digital patterns, analog or digital noise, etc.

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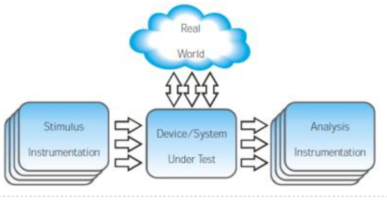


Laboratory power sources

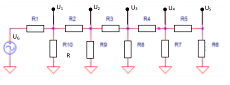
- DC voltage/current sources
  - Most common and often used for power of electronics in laboratory
  - With fixed of variable voltage and current (from 0V up to tens volts, current limitation from mA up to units of amperes)
  - Current limitation - the power source can be used as constant current source
  - Indication: measurement of real output voltage and current
- Reference sources (calibrators) - fixed voltage or current at a given condition (range of load, limited)
  - The output voltage/current is very accurate and precise
  - Used at calibration and checking the accuracy of other instrument of electronics circuit as the source of known stimulus

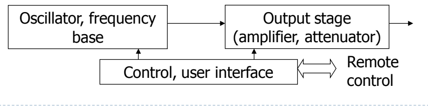
Basic parameters and requirements

- Quality (purity) of output waveforms (THD, linearity, rising, falling, etc.)
- Frequency range, stability (phase noise), spectral purity, distortion by an even or odd harmonics, etc.
- Range of output signal magnitude
- Output impedance (typically 50Ω, 300Ω)
- Signaling (type of output): grounded, floating, symmetrical, unsymetrical)
- Accessories and options

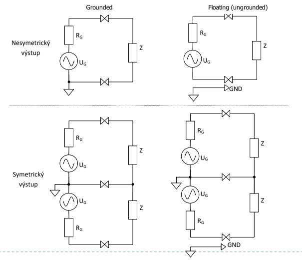
Principal block diagram

- Oscillator/Frequency base mainly determines:
  - Waveform shape a signal quality
  - Frequency range, phase noise
  - Optional modulations
- Output stage
  - Magnitude and quality (purity) of output signals
  - Output impedance (a constant accurate value is required)





Outputs



Indicators and displays

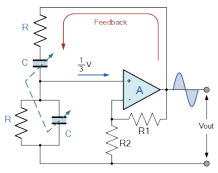
- Typically passive indicators
  - Set and indicated values come from calibrated output on matched load impedance (both are typically 50Ω)
  - Alternatively used can set different load, e.g., High Z means that used load impedance is much higher than generator output impedance (50Ω). Then the indicated output voltage is equal to the internal voltage source of generator
- Rarely active indicator (old analogue generators) = voltmeter measuring true voltage on generator output or counter measuring true frequency of generator.

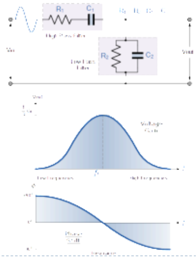
Harmonic LF generators

- Requirements:
  - Extremely low distortion (common analogue THD+noise<-60dB, quality - digital <-100dB)
  - Frequency range cca. 0,1Hz-100MHz (frequency stability 10^{-4} – 10^{-6})
  - Output voltage cca 1mV-10V/50Ω (75, 300, 600, voliteľná), accuracy better than 0,1%
- Principles:
  - Analogue (obsolete, low cost): RC oscillators, the most common: Wien oscillator
  - Digital: DDS (see arbitrary generators)

RC harmonic oscillators

- Only in low cost generators
  - The most common principle: Wien oscillator
    - Advantage: only two component need to be tuned in parallel



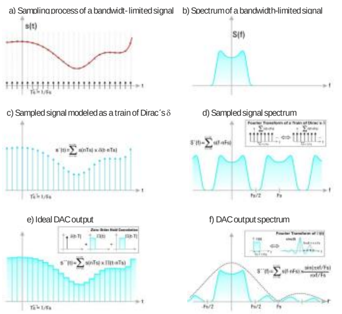


Arbitrary waveform generators (AWG)

- Frequency from mHz up GHz
- Basic common waveforms (sine, triangle, square sawtooth) + predefine waveforms in memory (sinc, cardiac, exponential, …) + noise (pseudorandom) + programmable waveforms from PC (arbitrary)
  - Basic analog and simple digital modulations (AM, FM, FSK, ASK, PSK, QAM)
- Principle of generation: Direct Digital Synthesis (DDS)
- Any samples may be stored in generator memory from PC or a memory stick

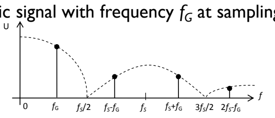
Sampling Theory

- AWG are based on sampling theory
- Bandwidth of generated signal is
- Properties or real DAC have important influence on linear distortion of generated signals



Spectrum of generated signal

- Let suppose harmonic signal with frequency f_G at sampling rate f_s:

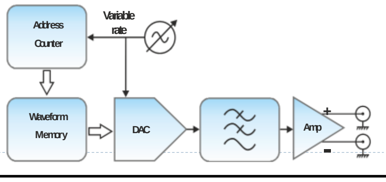


- Distortion is caused by the presence of spectral components over Nyquist frequency – they need to be rejected by a low pass filter

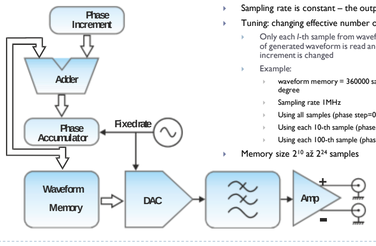
$$D[\mathrm{dBc}] = 20\log\frac{U_{alias}}{U_G} = 20\log\frac{\dfrac{\sin(\pi(f_{CLK}-f_G)/f_{CLK})}{\pi(f_{CLK}-f_G)/f_{CLK}}}{\dfrac{\sin(\pi f_G/f_{CLK})}{\pi f_G/f_{CLK}}} = 20\log\frac{\mathrm{sinc}(\pi(f_{CLK}-f_G)/f_{CLK})}{\mathrm{sinc}(\pi f_G/f_{CLK})}$$

Traditional architecture

- Samples covering one period of signal are stored in memory
- Distorted components have frequencies $kf_s \pm kf_g$
- If we change frequency of output signal by sampling rate changing, the output filter must be tuned by tracking the sampling rate – difficult or even not realizable in wide frequency range



Solution: DDS



- DDS – Direct Digital Synthesis
- Sampling rate is constant – the output filter is fixed
- Tuning: changing effective number of samples per period
  - Only each *l*-th sample from waveform memory containing samples from one period of generated waveform is read and converted into generated signal = phase increment is changed
  - Example:
    - waveform memory = 360000 samples per period - phase step = 360/360000= 0.001 degree
    - Sampling rate 1MHz
    - Using all samples (phase step=0.001deg): Tg=360000/1Mhz =0.36s - fg=2,77777Hz
    - Using each 10-th sample (phase step=0.01deg): Tg=36000/1Mhz =0,036 - fg=27,7777Hz
    - Using each 100-th sample (phase step=0.1deg): Tg=3600/1Mhz =0,0036 - fg=277,777Hz
- Memory size 2^{10} až 2^{24} samples

DDS parameters

- Frequency step – discrete: $\Delta_{f_{GLSB}} = \frac{f_{CLK}}{2^N}$,
- Frequency range:

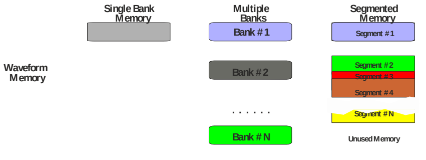
$$T_G = T_{CLK}\frac{360}{\phi} \Rightarrow f_G = \frac{1}{T_G} = \frac{1}{T_{CLK}}\frac{\phi}{360} = f_{CLK}\frac{\phi}{360}$$

- Distortion caused by quantization: DAC requires (16 až 24 bits):

$$SINAD = 20\log\frac{U_{rms}}{\varepsilon_{rms}} = 20\log\frac{2^{B-1}\cdot\sqrt{2}}{1/\sqrt{12}} = 20\log\left(2^B\sqrt{6}\right)$$

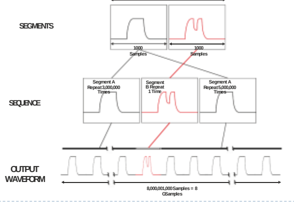
Memory segmentation

- Record Length (RL) and Sampling Rate (SR) determine Time Window (TW)
  - TW = RL/SR



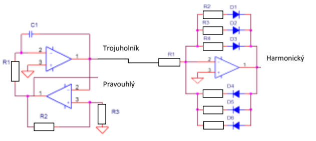
Memory segmentation and sequencing

- Memory segmentation and segment sequencing enable much longer effective time window



Analogue function generators

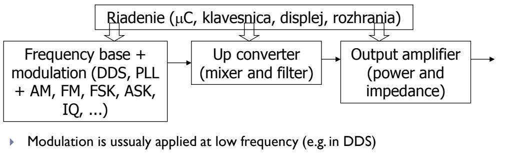
- Only in low cost and low quality generators.
- Principle: multivibrator generating triangular together with square pulse waveform
  - Harmonic waveform is generated by nonlinear circuit from triangular waveform
    - A part of FET quadratic transfer characteristic
    - Amplifier with controlled gain



RF and microwave gemnerators

- Output: harmonic waveform with frequency above MHz up tens GHz
- Modulation (internal, external, analog digital)
- Output voltage from μV up to V,
- Fixed output impedance is very important
- Stability of frequency and signal purity are very important parameters of these generators
- Základné bloky: oscilátor/frekvenčná základňa, modulátory, koncový stupeň, riadenie

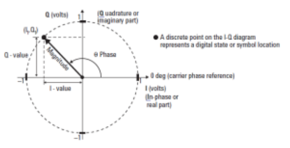
Basic blocks

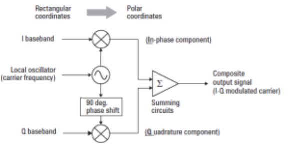


- Modulation is ussualy applied at low frequency (e.g. in DDS)
- Up converter transpone low frequency modulated signal on required RF frequency on generator output
  - Important: bandwidth in low frequency (wide enables generate complex digital modulations)

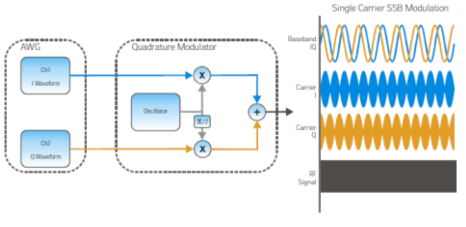
QAM

- Universal principle of modulator - any modulation can be generated by the same HW according to two modulation components:
  - I (in-phase – real part)
  - Q (quadrature – imaginary part).
  - Modulator converts cartesian coordinates of carrier to polar and applied them on carrier





Combination of DDS and vector modulation



Pulse generators

- Needed for measurement in digital systems
- Simple generator of pulse trains:
  - Generate periodical of burst pulse signals with settable rate, pulse width, amplitude, offset (L and H level), rise and fall times, number of pulse in a burst, etc.
  - Offer one or two outputs with programmable delay
  - Additional inputs and outputs:
    - Clock input/output
    - Trigger input/output with programmable delay
- Pattern generators
  - Generate parallel data words train (patterns)
  - The words as well as electrical and time parameters of output signals are programmable
  - Applications: emulation of control and status signals or buss signals from different logic, e.g. microprocessor, input/output circuit, development of FPGA content, etc.

Important notes

- RF and pulse generators: generators need to be matched to the load
  - Standing waves
  - Distortion of pulse shape.
  - Generator accessories: different impedance converters, attenuators, connector convertors, etc.