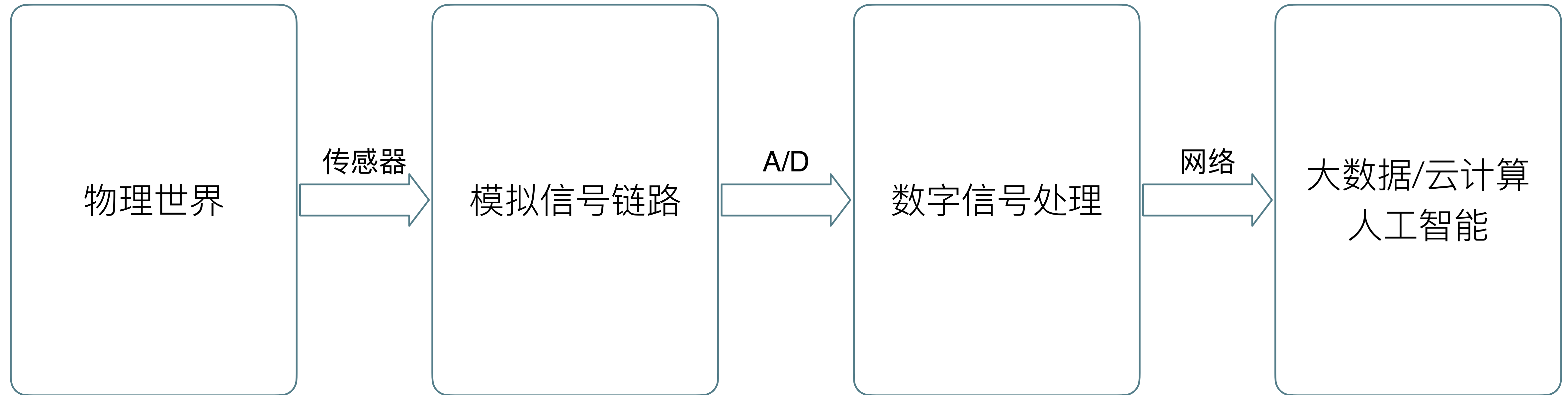


电子产品的系统构成及电路基础

由电流构成的回路，由电压/电流表征的信号

所有电子产品都是用电信号对物理世界进行表征和计算的过程



$$V=I \cdot R$$

时域

频域

数字域

基本的电路理论

主要公式

Ohm's Law

Power (P)
The total work performed by a current

Voltage (V)
Electrical force or pressure

Current (I)
The number of electrons passing in a single point

Resistance (R)
Resistance to the flow of current

$P = V \times I$
 $V = \sqrt{P \times R}$
 $I = \sqrt{\frac{P}{R}}$
 $R = \frac{V}{I}$
 $V = R \times I$
 $P = R \times I^2$
 $I = \sqrt{\frac{P}{R}}$

Basic Units

Quantity	Unit
Capacitance	F Farad
Charge	C Coulomb
Current	A Ampere
Energy	J Joule
Force	N Newton
Frequency	Hz Hertz
Inductance	H Henry
Magnetic Flux	Wb Weber
Potential	V Volt
Power	W Watt
Resistance	Ω Ohm

Kirchhoff's Laws

Closed Loop Rule
The directed sum of the electrical potential differences (voltage) around any closed circuit is zero

$\sum \Delta V_{\text{close loop}} = 0$

$V_{AB} + V_{BC} + V_{CD} + V_{DA} = 0$

Junction Rule
The sum of currents entering the junction are thus equal to the sum of currents leaving.

$\sum I_{in} = \sum I_{out}$

$I_1 = I_2 + I_3$

Resistor Network

Series
 $R_T = R_1 + R_2 + R_3$

Parallel
 $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

Capacitor Network

Series
 $\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

Parallel
 $C_T = C_1 + C_2 + C_3$

Unit Prefixes

Prefix	Symbol	Factor
Tera	T	$\times 10^{12}$
Giga	G	$\times 10^9$
Mega	M	$\times 10^6$
Kilo	K	$\times 10^3$
Hecto	H	$\times 10^2$
Deka	Da	$\times 10^1$
(base)	-	$\times 10^0$
Deci	d	$\times 10^{-1}$
Centi	c	$\times 10^{-2}$
Milli	m	$\times 10^{-3}$
Micro	μ	$\times 10^{-6}$
Nano	n	$\times 10^{-9}$
Pico	p	$\times 10^{-12}$

examples:
 $25 \mu A = 25 \times 10^{-6} A = 0.000025 A$
 $4.7 M\Omega = 4.7 \times 10^6 \Omega = 4,700,000 \Omega$

Alternating Current

Peak Positive Voltage (Vp+)

Peak Negative Voltage (Vp-)

Peak-to-Peak Voltage (Vpp)

RMS Voltage (VRMS)

Average AC Voltage
 $= 0.637 \times \text{Peak}$
 $= 0.9 \times \text{RMS}$

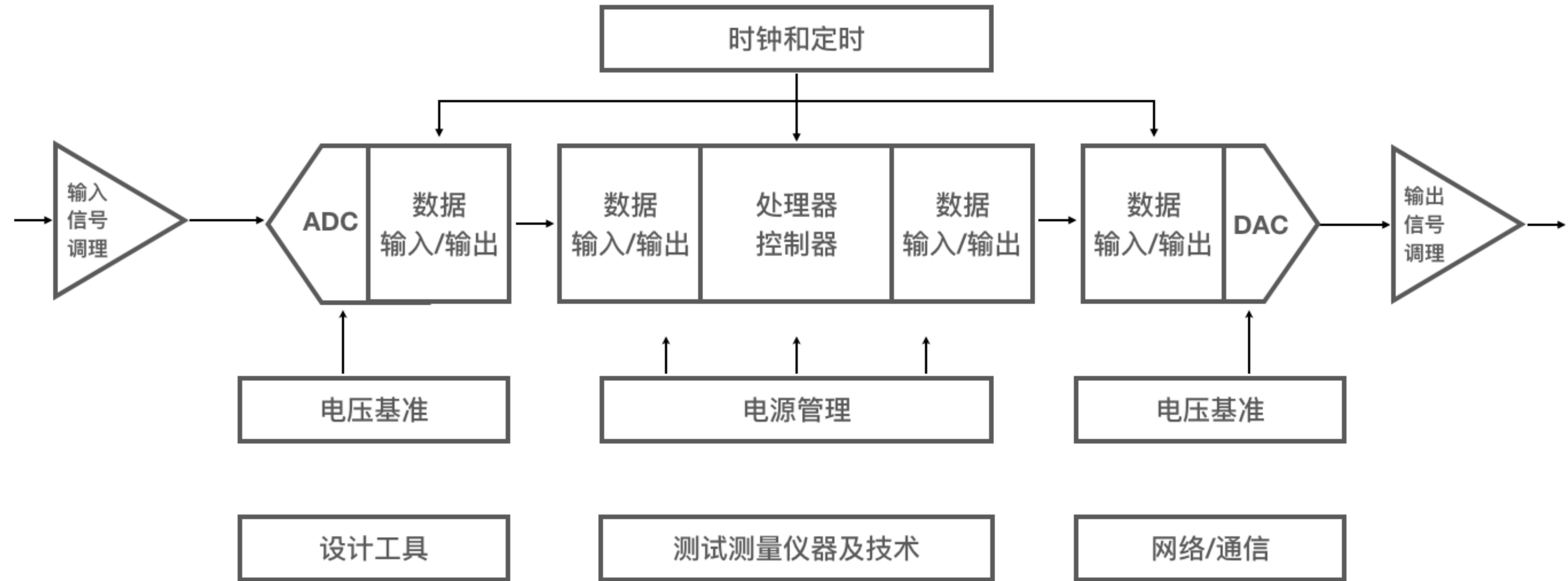
RMS AC Voltage
 $= 0.707 \times \text{Peak}$
 $= 1.11 \times \text{Average}$

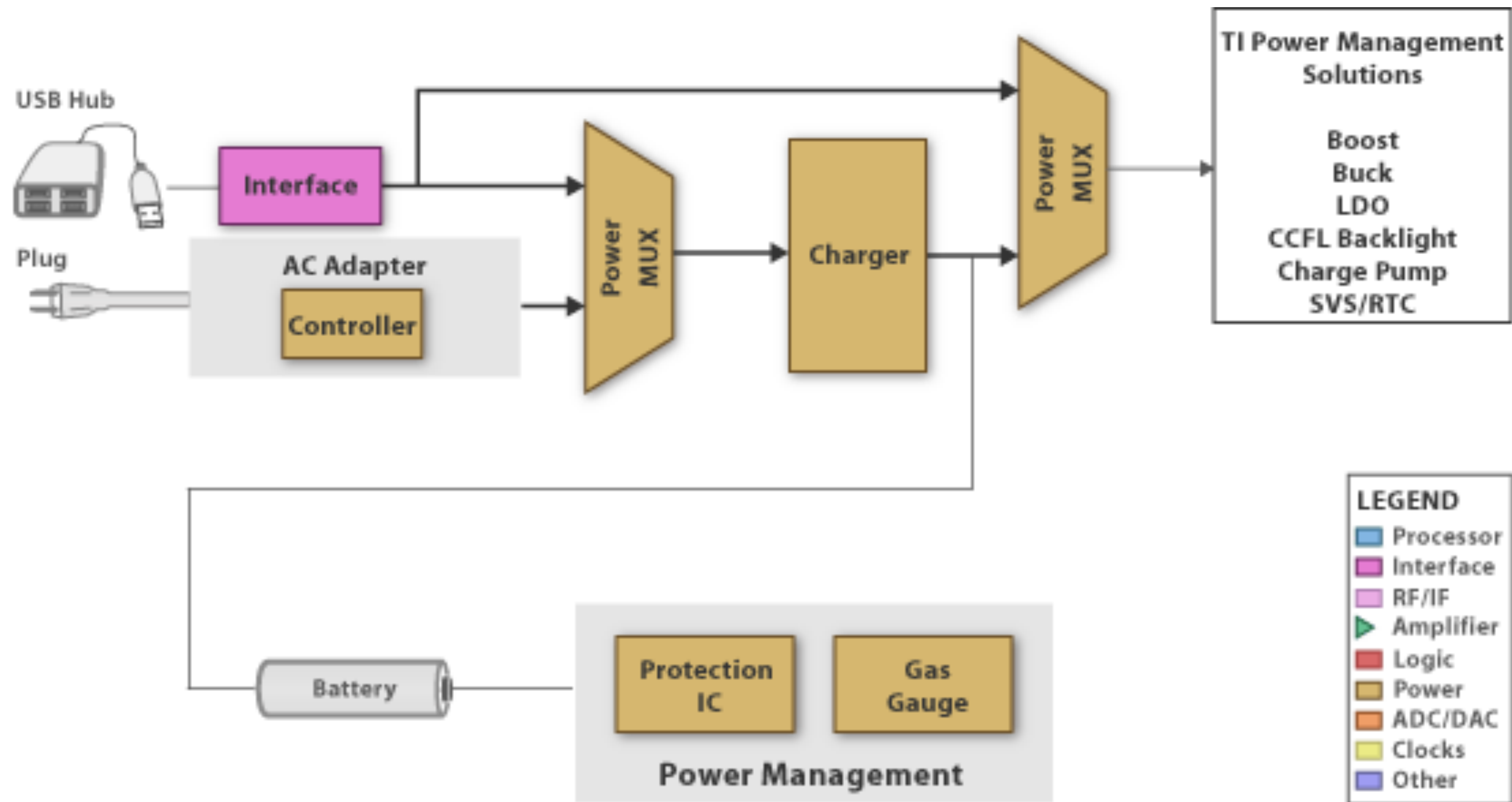
Peak AC Voltage
 $= 1.414 \times \text{RMS}$
 $= 1.57 \times \text{Average}$

Basic Electronics Theory www.josericafort.com/shop
 Email: me@josericafort.com

Parameter	Symbol	Measuring Unit	Description
Voltage	Volt	V or E	Unit of Electrical Potential $V = I \times R$
Current	Ampere	I or i	Unit of Electrical Current $I = V \div R$
Resistance	Ohm	R or Ω	Unit of DC Current $R = V \div I$
Conductance	Siemen or Mho	G or σ	Unit of Conductance $G = 1 \div R$
Power	Watts	W	Unit of Power $P = V \times I$
Capacitance	Farad	C	Unit of Capacitance $C = Q \div V$
Inductance	Henry	L or H	Unit of Inductance $V_L = -L(di \div dt)$
Impedance	Ohm	Z	Unit of AC Resistance $Z^2 = R^2 + X^2$
Charge	Coulomb	Q	Unit of Electrical Charge $Q = C \times V$
Frequency	Hertz	Hz	Unit of Frequency $f = 1 \div T$
Period	sec	s	Unit of Period $T = 1 \div f$

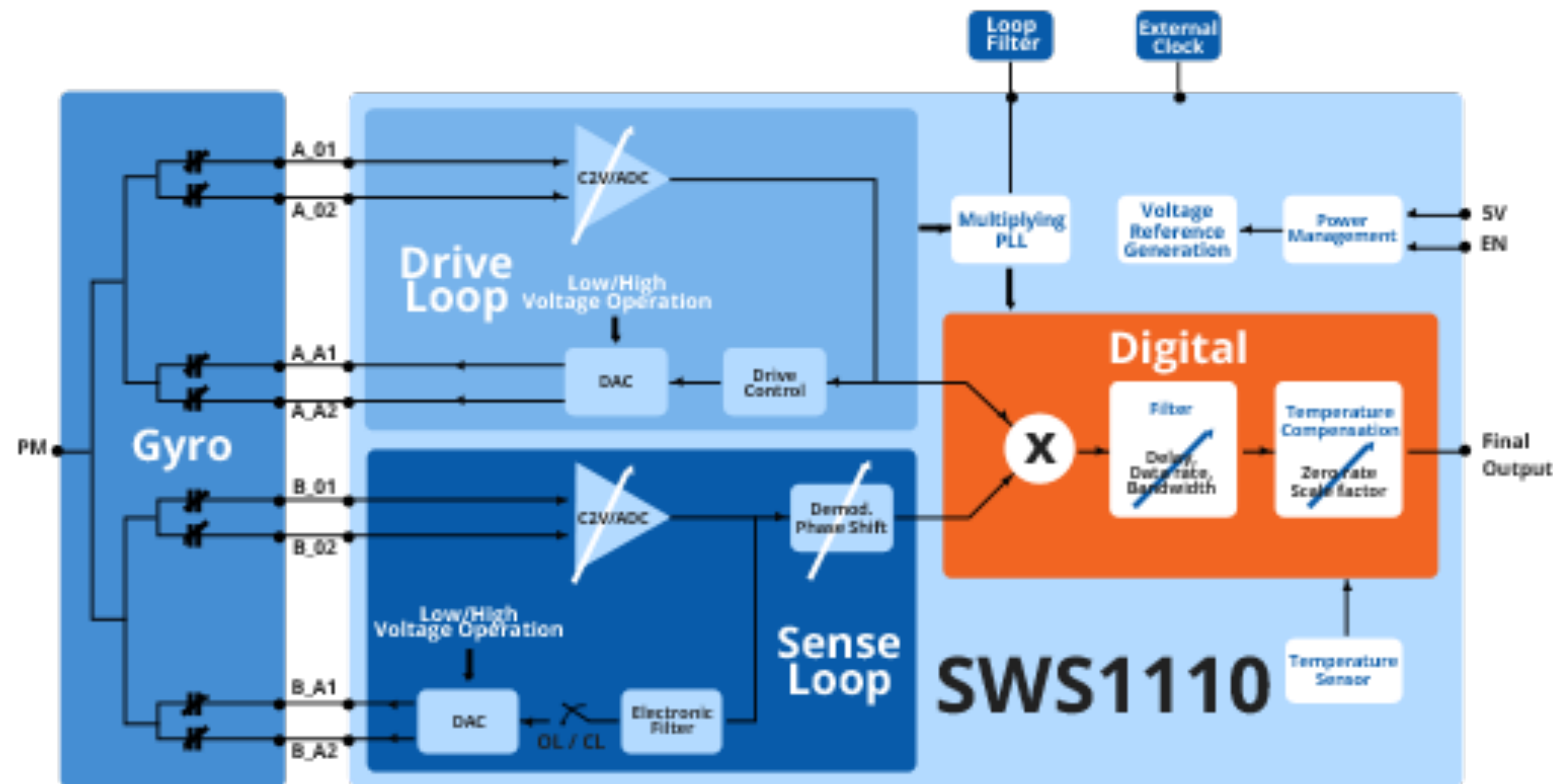
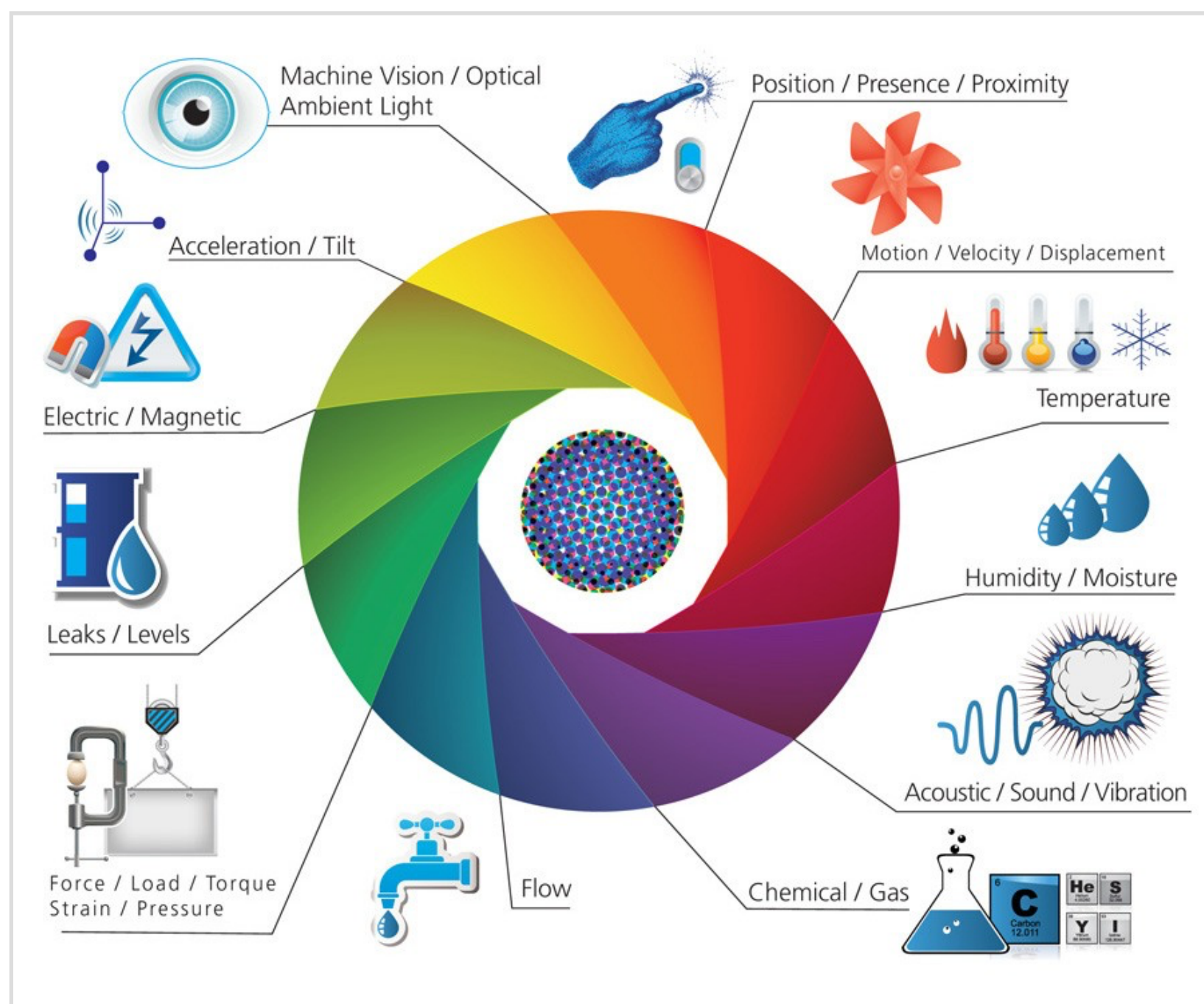
电子产品系统构成





电源部分

所有电子产品都需要供电

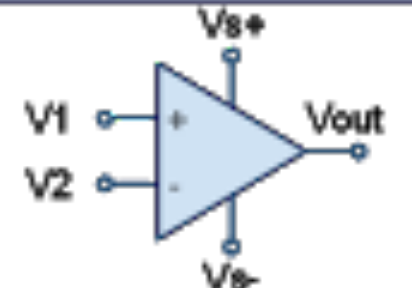
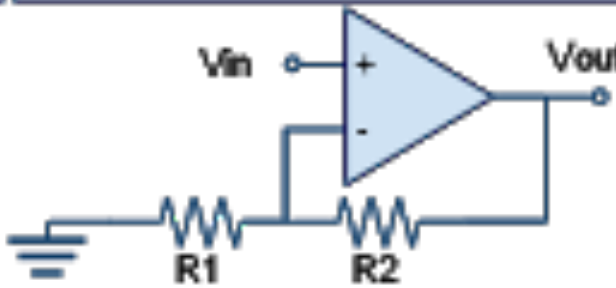
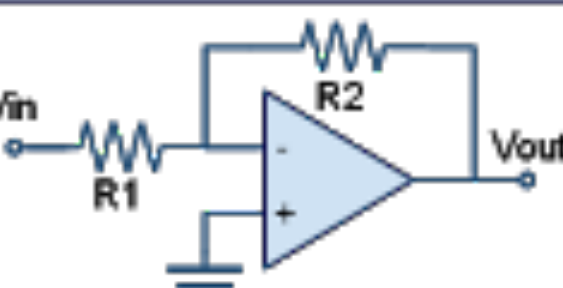
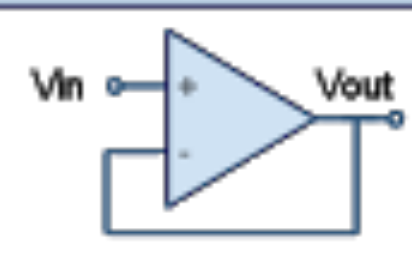
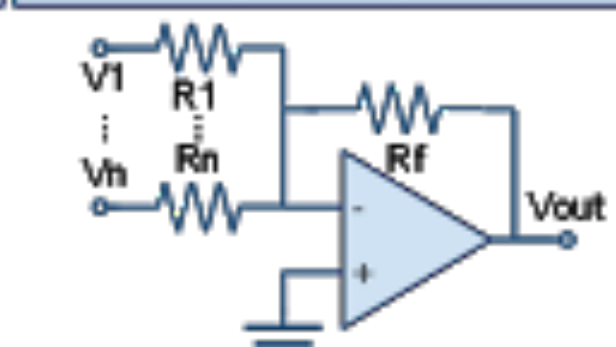
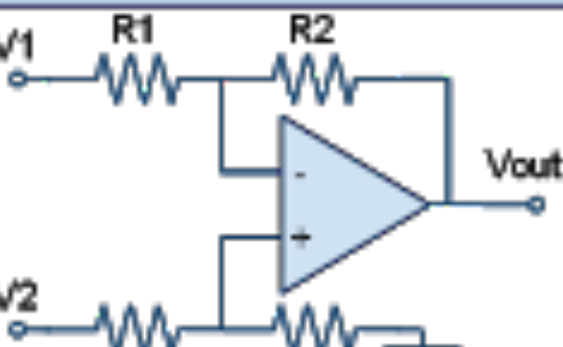
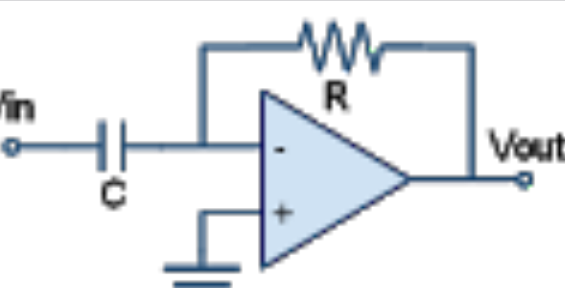
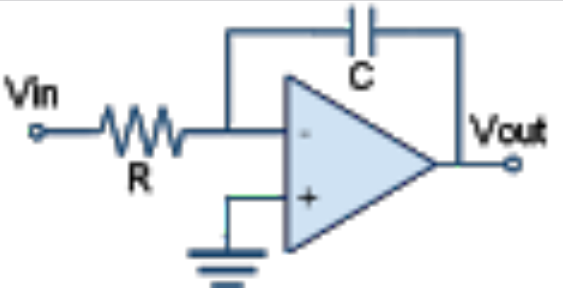


传感器 - 物理信号转变为电信号

对物理世界用电信号进行表征

模拟信号调理 - 幅度调节: 放大/衰减

Basic Operational Amplifier Configurations

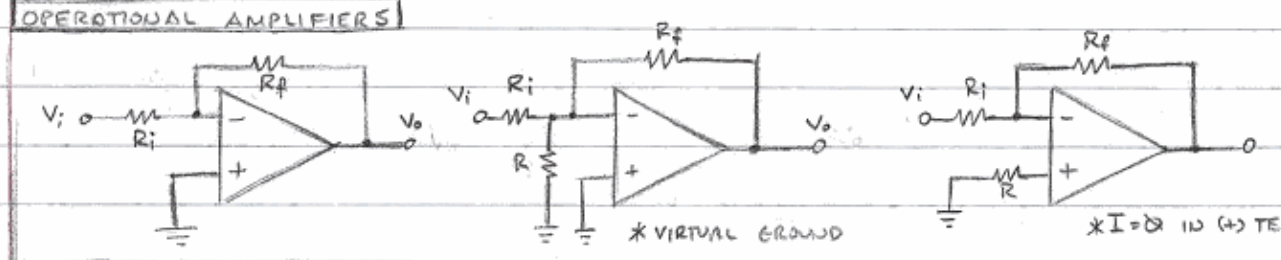
<p style="text-align: center;">Voltage Comparator</p>  <p style="text-align: center;">V_{s+} V_{s-}</p> <p style="text-align: center;">$V_{out} = \begin{cases} V_{s+} & V1 > V2 \\ V_{s-} & V1 < V2 \end{cases}$</p>	<p style="text-align: center;">Non-Inverting Amplifier</p>  <p style="text-align: center;">$V_{out} = V_{in} \cdot \left(1 + \frac{R2}{R1}\right)$</p>	<p style="text-align: center;">Inverting Amplifier</p>  <p style="text-align: center;">$V_{out} = -V_{in} \cdot \left(\frac{R2}{R1}\right)$</p>
<p style="text-align: center;">Voltage Follower</p>  <p style="text-align: center;">$V_{out} = V_{in}$</p>	<p style="text-align: center;">Inverting Summing Amplifier</p>  <p style="text-align: center;">$V_{out} = -R_f \cdot \left(\frac{V1}{R1} + \dots + \frac{Vn}{Rn}\right)$</p>	<p style="text-align: center;">Differential Amplifier</p>  <p style="text-align: center;">$V_{out} = \left(1 + \frac{R2}{R1}\right) \left(\frac{R4}{R3 + R4}\right) \cdot V2 - \left(\frac{R2}{R1}\right) \cdot V1$ If $R1 = R3$ and $R2 = R4$ Then $V_{out} = \left(\frac{R2}{R1}\right) (V2 - V1)$</p>
<p style="text-align: center;">Differentiator Amplifier</p>  <p style="text-align: center;">$V_{out} = -R \cdot C \cdot \left(\frac{dV_{in}}{dt}\right)$</p>	<p style="text-align: center;">Integrator Amplifier</p>  <p style="text-align: center;">$V_{out} = -\left(\frac{1}{R \cdot C}\right) V_{in} dt$</p>	

COMMON EQNS:
 $I = \frac{V}{R} = I \cdot R$ $I = \frac{P}{V} = \frac{P}{I}$
 $V_o = V_i \left(\frac{R_2}{R_1 + R_2}\right)$
 $V_{rms} = \frac{1}{\sqrt{2}} V$

NASH ECE 3813 TEST 1 NOTE SHEET

OPERATIONAL AMPLIFIERS

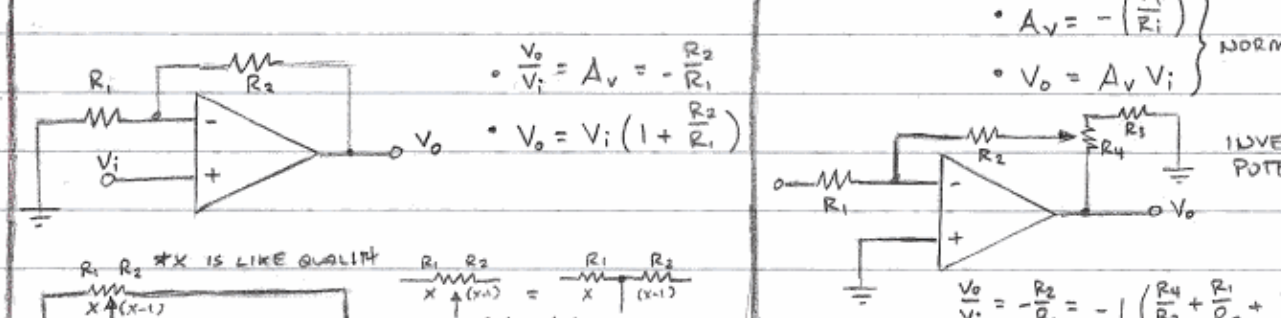
INVERTING



* VIRTUAL GROUND * $I = I_1 = I_2$ (KCL TERM)

• $A_v = -\left(\frac{R_f}{R_i}\right)$ NORMAL
 • $V_o = A_v V_i$

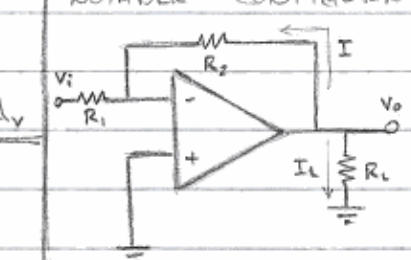
NON-INVERTING



* X IS LIKE QUALITY $\frac{R_1 R_2}{X + (X-1)}$ $\frac{R_1 R_2}{X + (X-1)}$ $\frac{R_1 R_2}{X + (X-1)}$
 $1 \neq \frac{1}{\infty}$

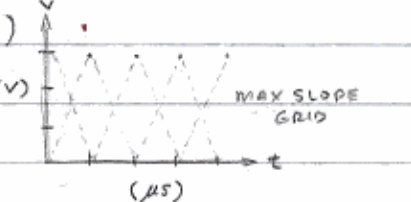
• $A_v(x) = \frac{1}{x} = \frac{1}{R_i}$ IF NO R_b
 $R_b = \max R$ FROM POT. • $\frac{V_o}{V_i} = 1 + \frac{(1-x)R_m}{x(R_m + R_b)} = 1 + \frac{R_s}{R_i + R_b} = A_v$

NOTABLE CONFIGURATIONS



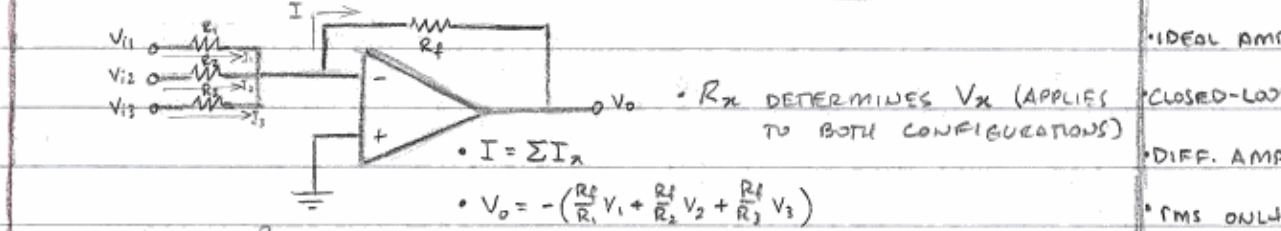
• $I_L = \frac{V_o}{R_L}$
 • $V_o = A_v (V_i)$
 • $V_o = I R_2 + I_L R_L$
 • $I_o = I_L + I = \frac{V_o}{R_2} + \frac{V_o}{R_L}$

SLEW = $\frac{V}{t} = \text{SLOPE (m)}$



$V(t) = m t$ (V) MAX SLOPE GRID
 $t_m = \frac{V}{m}$ (μs)

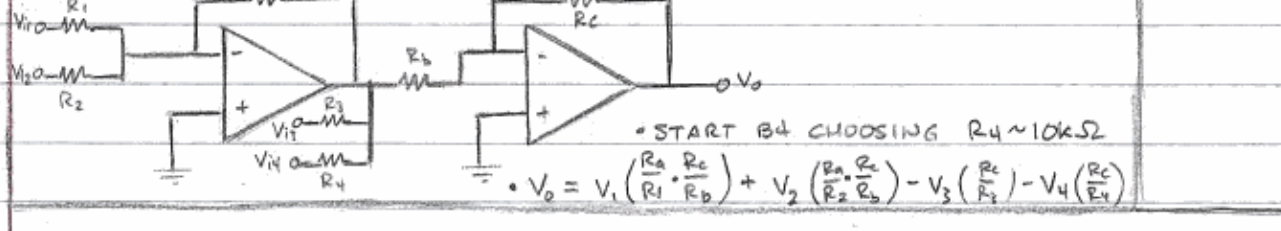
SUMMING AMPS



• R_x DETERMINES V_x (APPLIES TO BOTH CONFIGURATIONS)
 • $I = \sum I_x$
 • $V_o = -\left(\frac{R_f}{R_1} V_1 + \frac{R_f}{R_2} V_2 + \frac{R_f}{R_3} V_3\right)$

IDEAL AMPS HAVE HIGH R_i /LOW R_o
 CLOSED-LOOP AMPS: $A_v \approx 1$
 DIFF. AMP IDEAL TO ELIM. V_{cm}
 * RMS ONLY FOR POWER CALCULATIONS

DIFFERENCE AMP



• START BY CHOOSING $R_4 \sim 10k\Omega$
 • $V_o = V_1 \left(\frac{R_2}{R_1} \frac{R_4}{R_3 + R_4}\right) + V_2 \left(\frac{R_2}{R_2} \frac{R_4}{R_3 + R_4}\right) - V_3 \left(\frac{R_2}{R_1}\right) - V_4 \left(\frac{R_2}{R_1}\right)$

USING SUPERPOS: 1. SET V_{i1} TO G, CALC $V_{i2} \rightarrow V_{o1} = \left(\frac{R_2}{R_1}\right) V_{i1}$
 2. SET V_{i2} TO G, CALC $V_{i1} \rightarrow V_{o2} = V_{i2} \left(\frac{R_2}{R_1}\right)$
 3. CALC. $V_{i3} \rightarrow V_{o3} = \frac{R_2}{R_1} (V_{i3} - V_{i1}) = \frac{R_2}{R_1} V_{i3}$
 4. CALC DIFF. GAIN $\rightarrow A_d = \frac{2R_2}{R_1}$

TYPICAL TO ASSUME $R_1 = R_3$ AND $R_2 = R_4$ SO $\frac{R_2}{R_1} = \frac{R_4}{R_3}$

• $R_{id} = 2R_1$ * R_{id} = DIFFERENTIAL INPUT R
 • $A_d = \frac{R_2}{R_1} = \frac{R_4}{R_3}$ * A_d = DIFFERENTIAL GAIN, A_{cm} = COMMON MODE GAIN

• $V_o = A_d (V_1 - V_2)$ * (IDEAL, $R_1 = R_3$ & $R_2 = R_4$)
 • $V_o = A_d (V_1 - V_2) + \frac{1}{2} A_{cm} (V_1 + V_2)$ • $V_o = \left(\frac{R_2 + R_1}{R_4 + R_3}\right) \left(\frac{R_4}{R_1}\right) V_{i2} - \left(\frac{R_2}{R_1}\right) V_{i1}$ (NON-IDEAL)

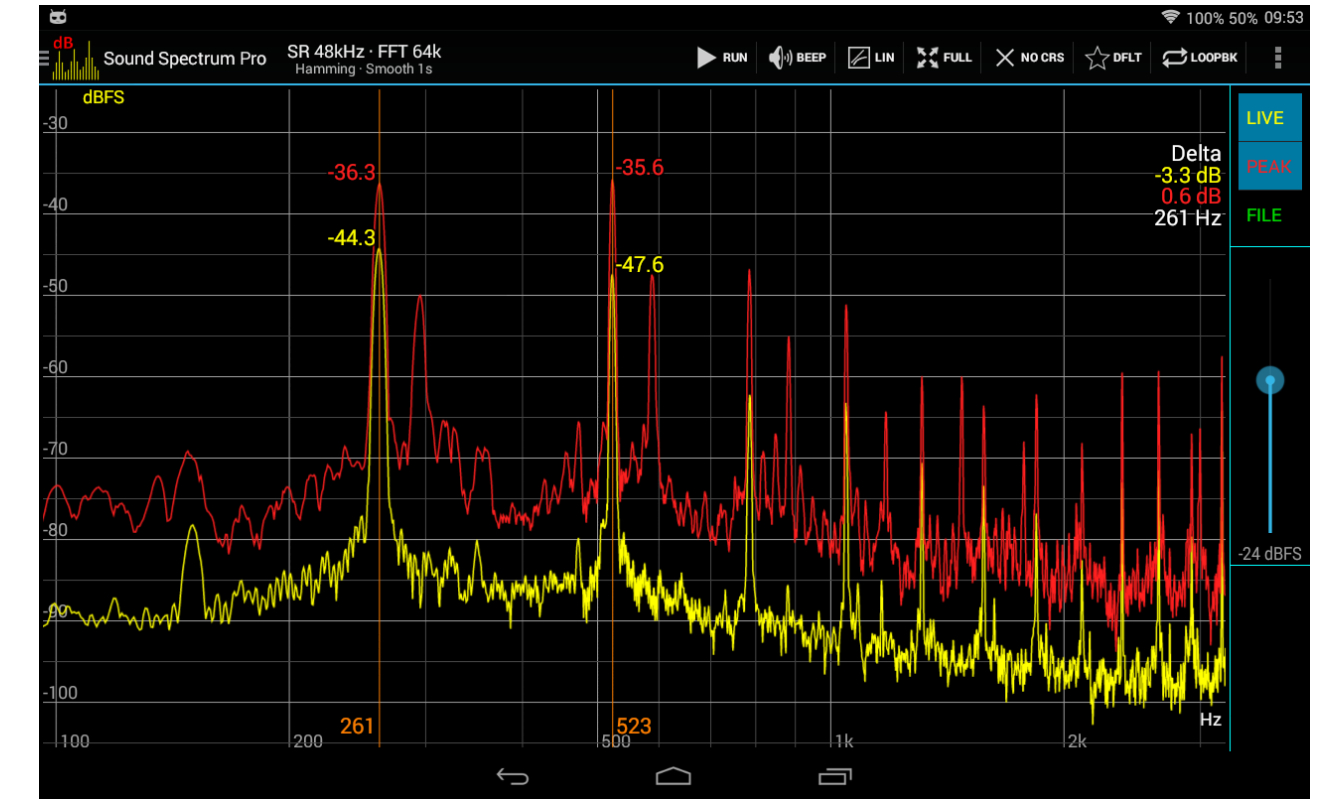
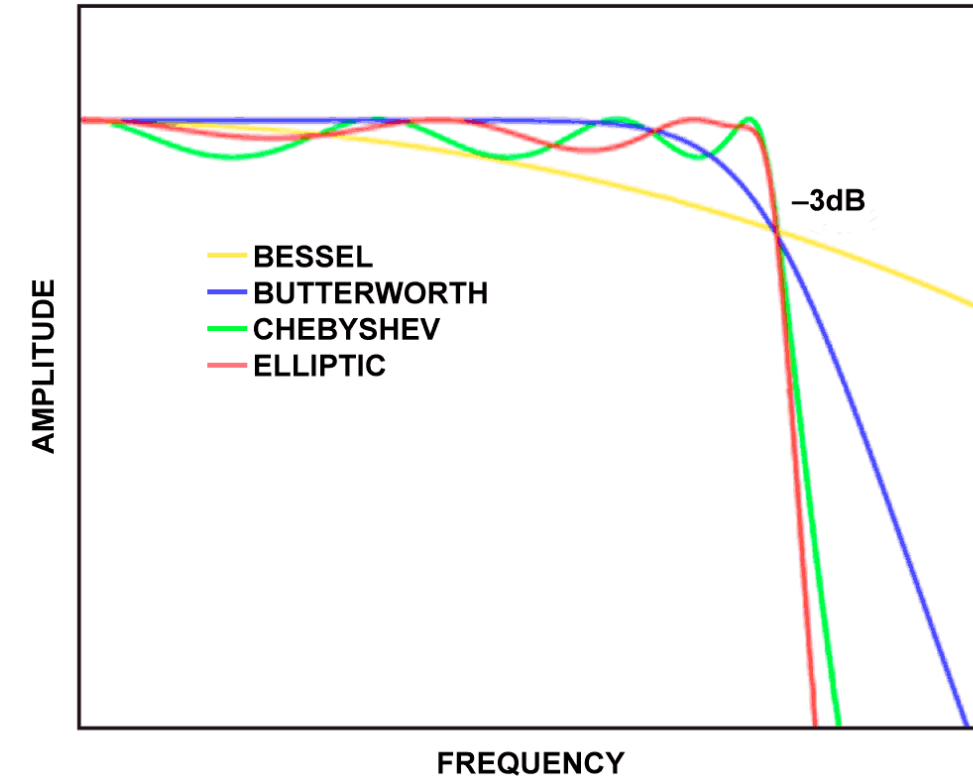
CMRR = $\frac{A_d}{A_{cm}}$
 CMRR = $20 \log \left(\frac{A_d}{A_{cm}}\right)$

CMRR = COMMON MODE REJECTION RATIO; MEASURES ABILITY OF AMP TO ACCURATELY CANCEL VOLTAGES

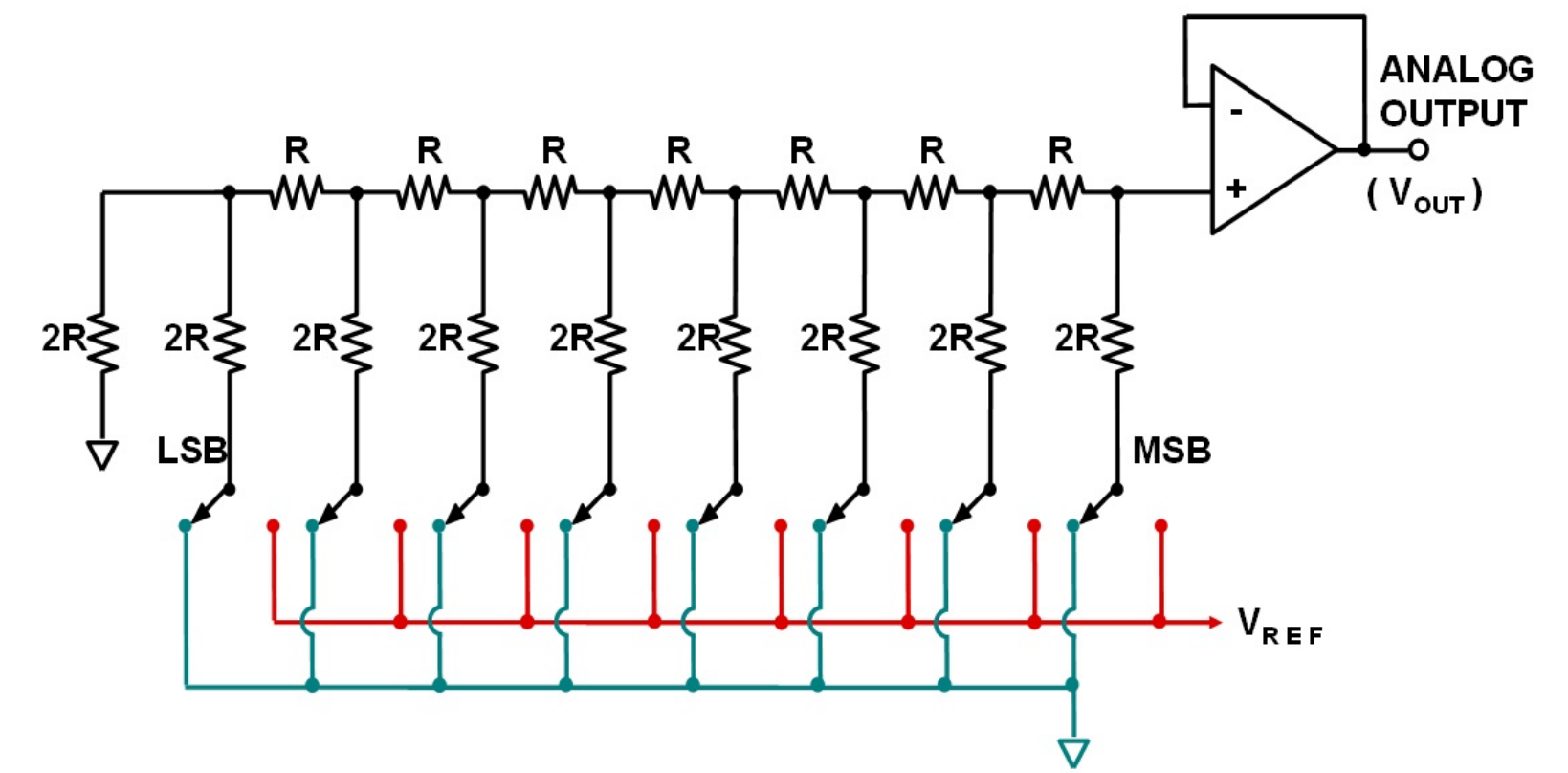
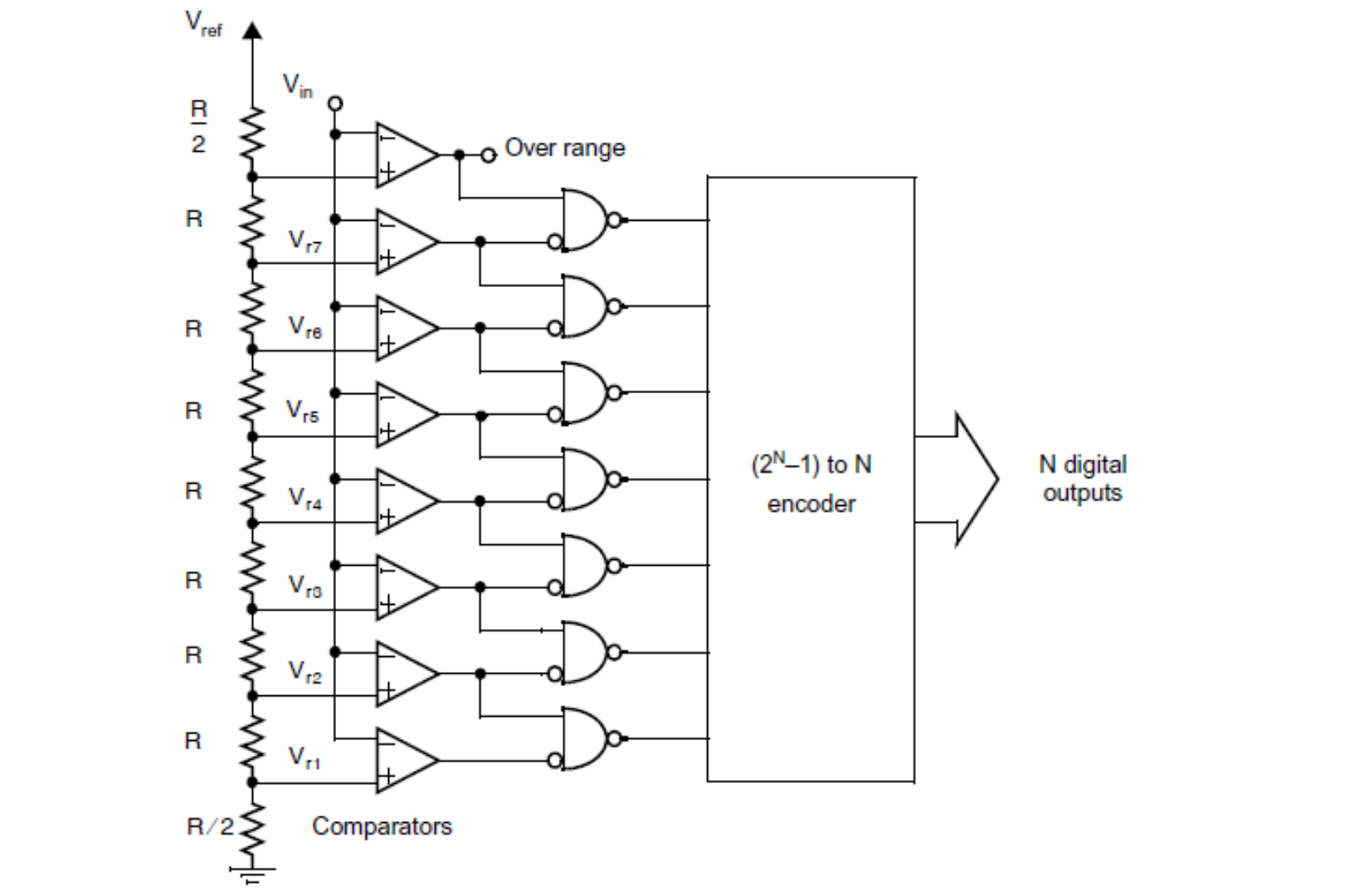
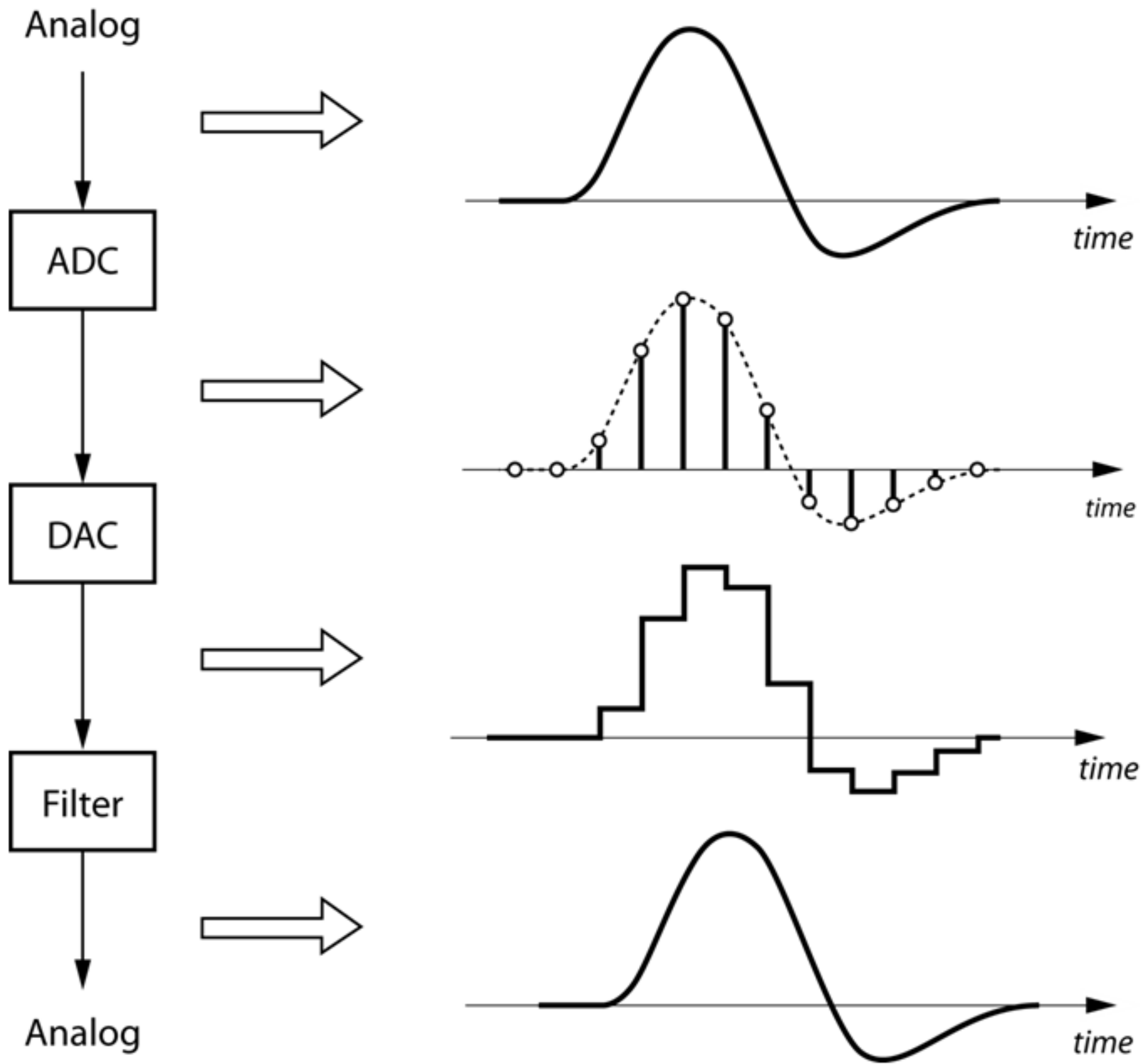
M. Nash
2010

模拟信号调理 - 频域：滤波器

- 主要类型：低通、带通、高通
- 主要指标：
 - 过渡带衰减
 - 抑制度
 - 带内波动
 - 相位特性
- 有源滤波/无源滤波
- 测量仪器 - FFT/频谱仪



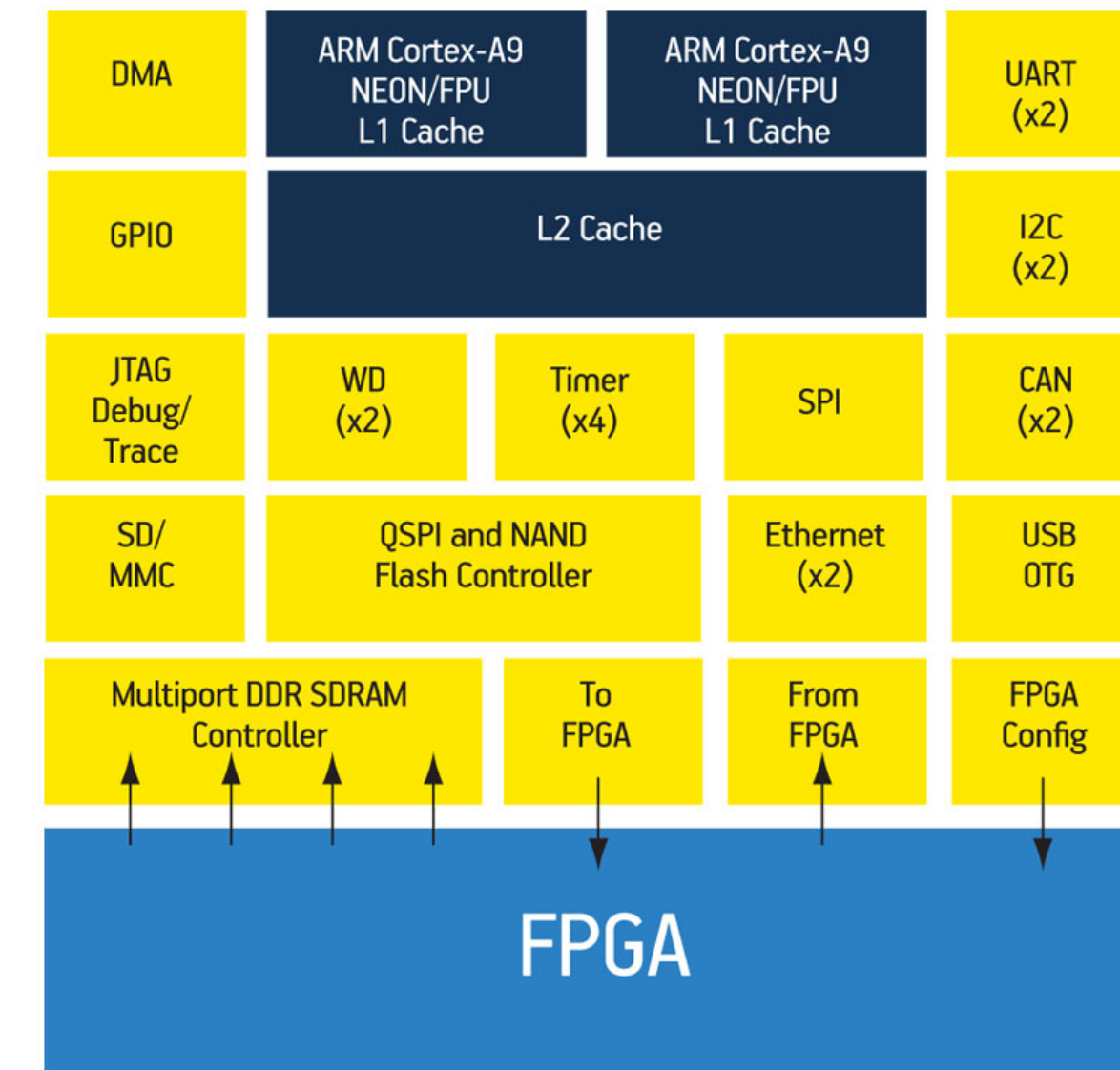
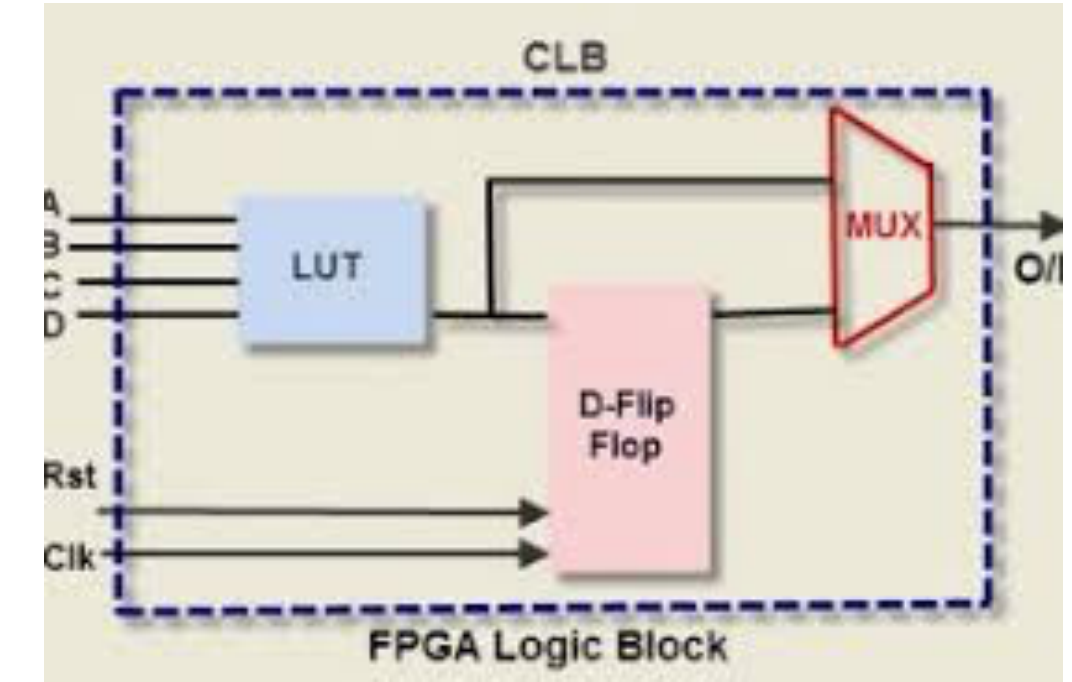
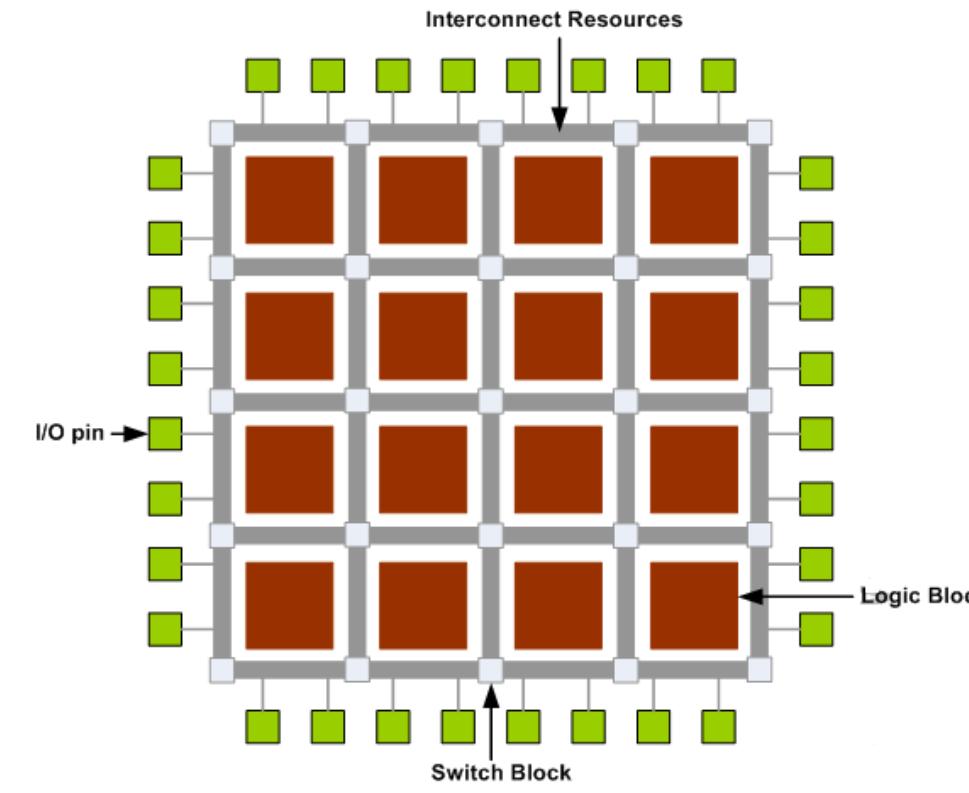
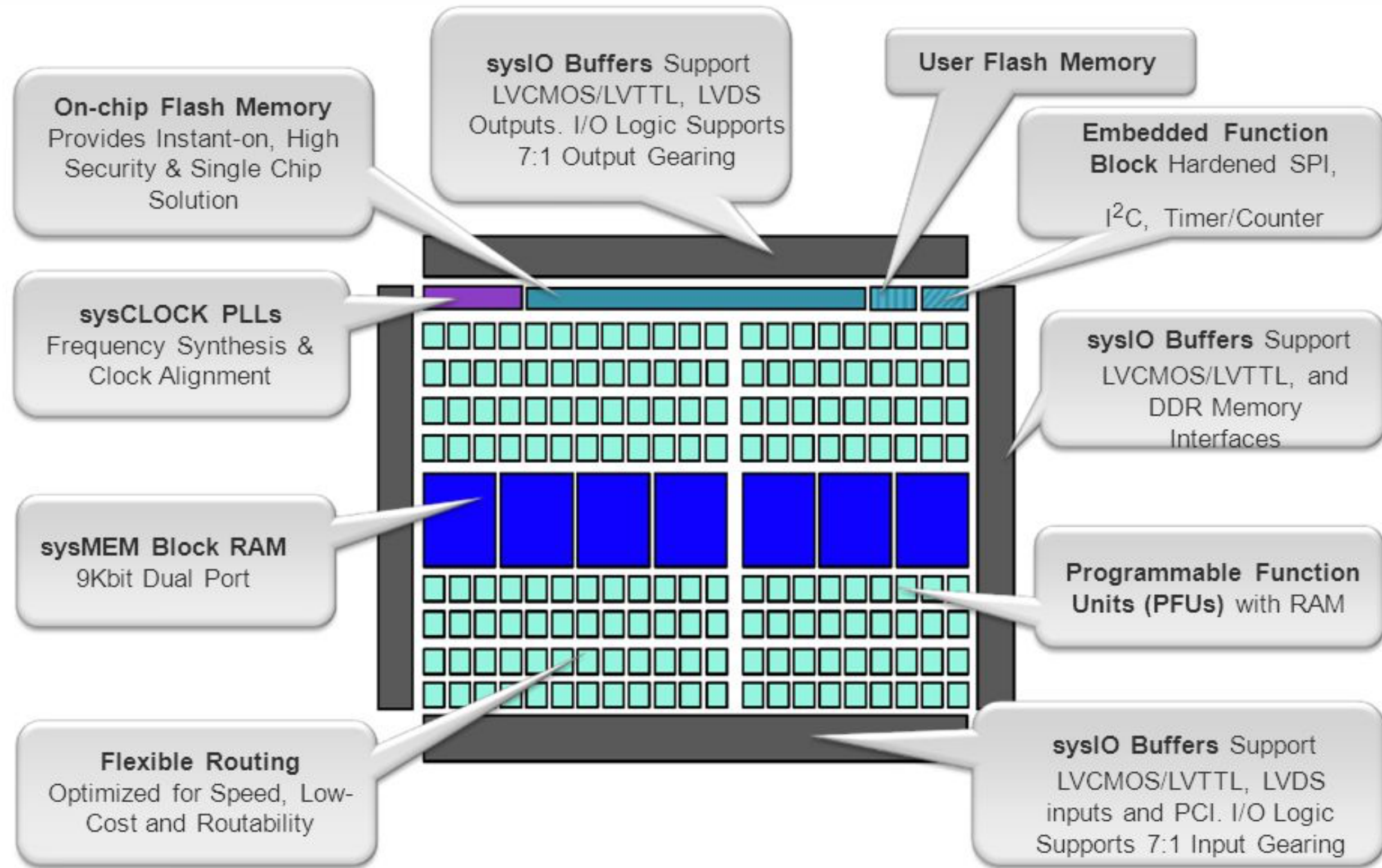
	过度带 衰减速度	通带内起伏	通带外抑制	相位特性
贝塞尔滤波器	非常慢	带内无起伏, 单调衰减	衰减慢	通带内的相 应近乎线性
巴特沃斯滤波器	比较慢	无起伏, 最平坦	单调衰减	
切比雪夫滤波器	比较快	有起伏, 等波纹	单调衰减	
椭圆滤波器	非常快	有起伏, 等波纹	有起伏, 等波纹	良好



数据转换 - ADC/DAC: 连接模拟信号和数字信号的桥梁 - 转换率/分辨率

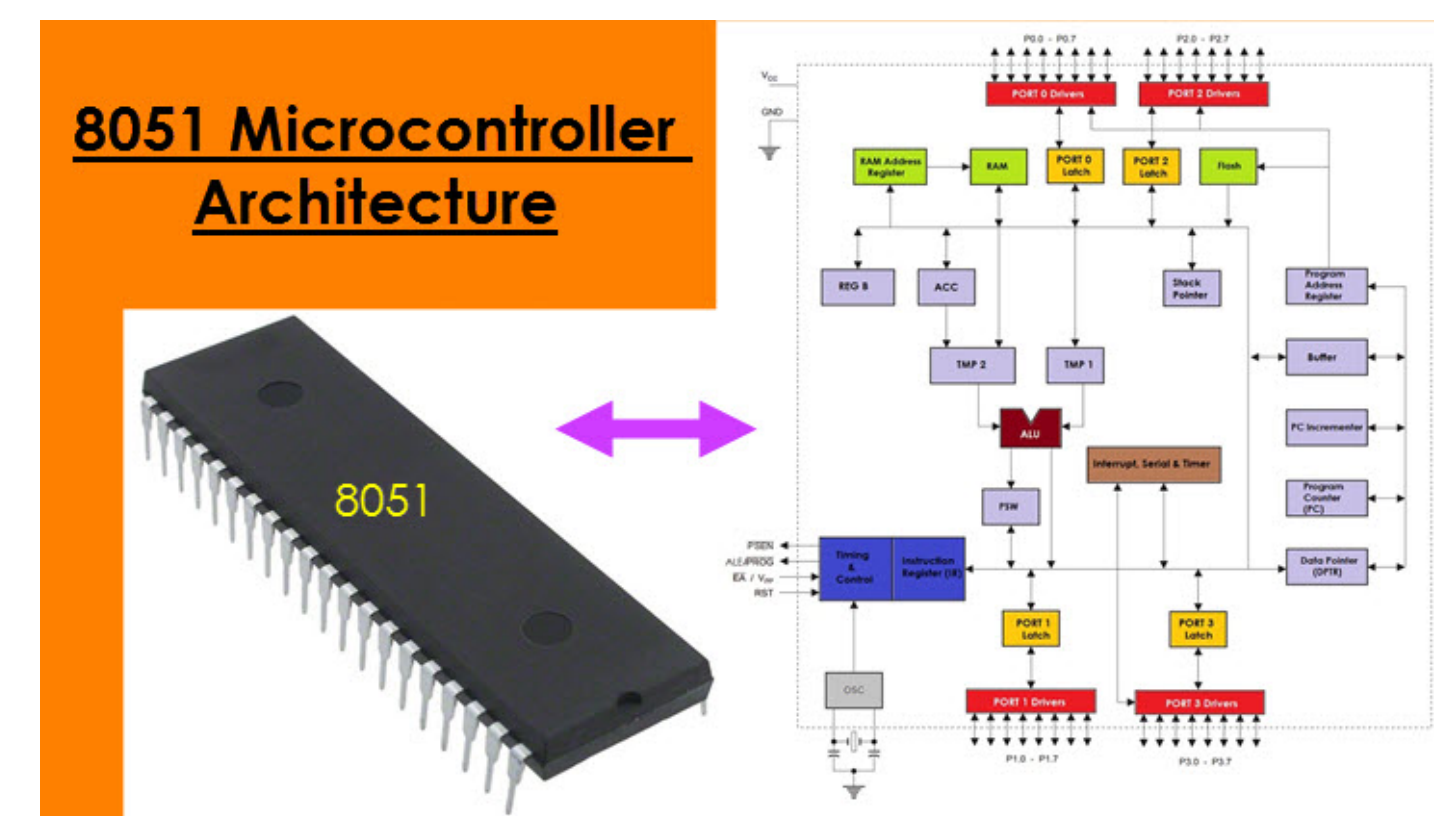
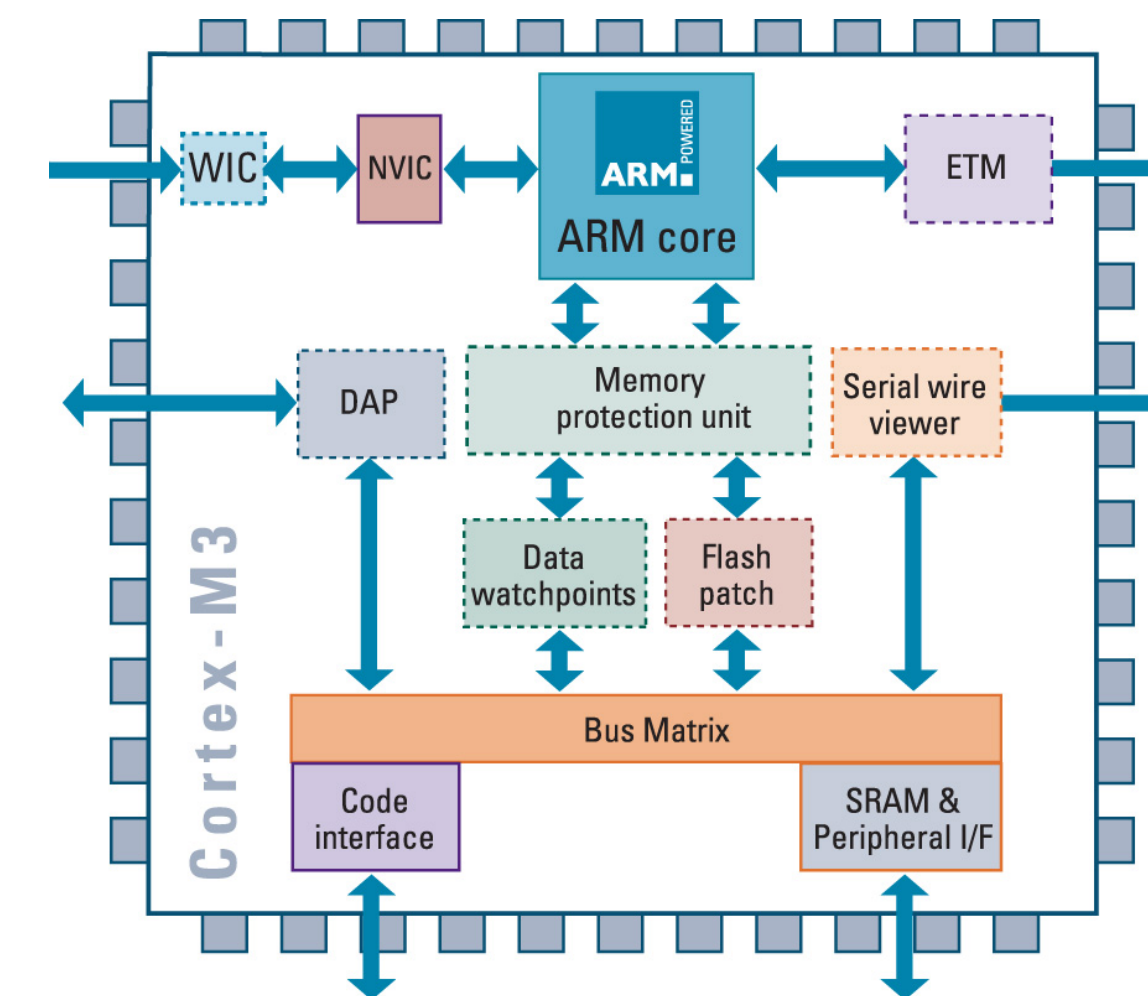
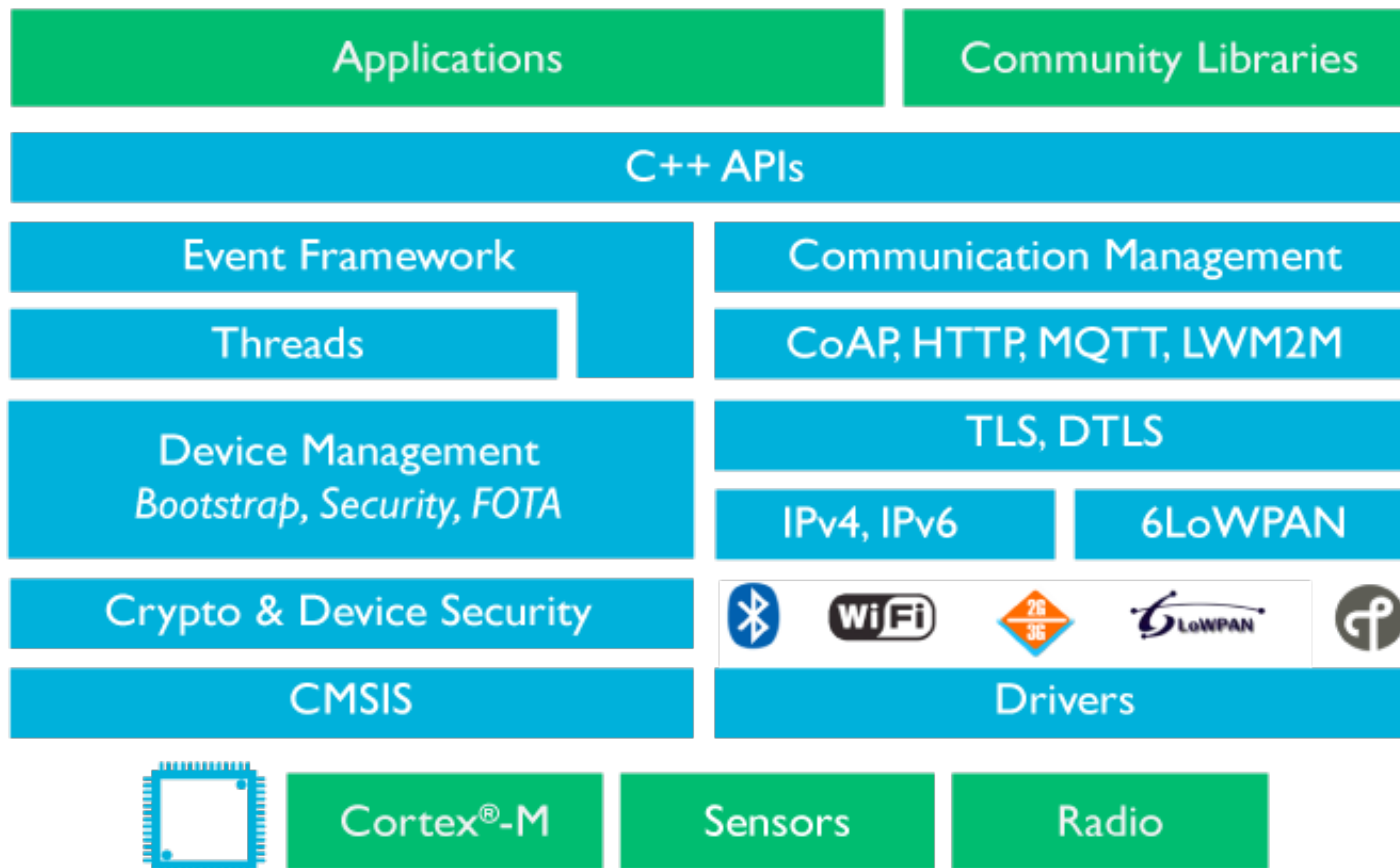
MACHXO2 BLOCK DIAGRAM (XO2-1200)

'Value added' features in and around the core



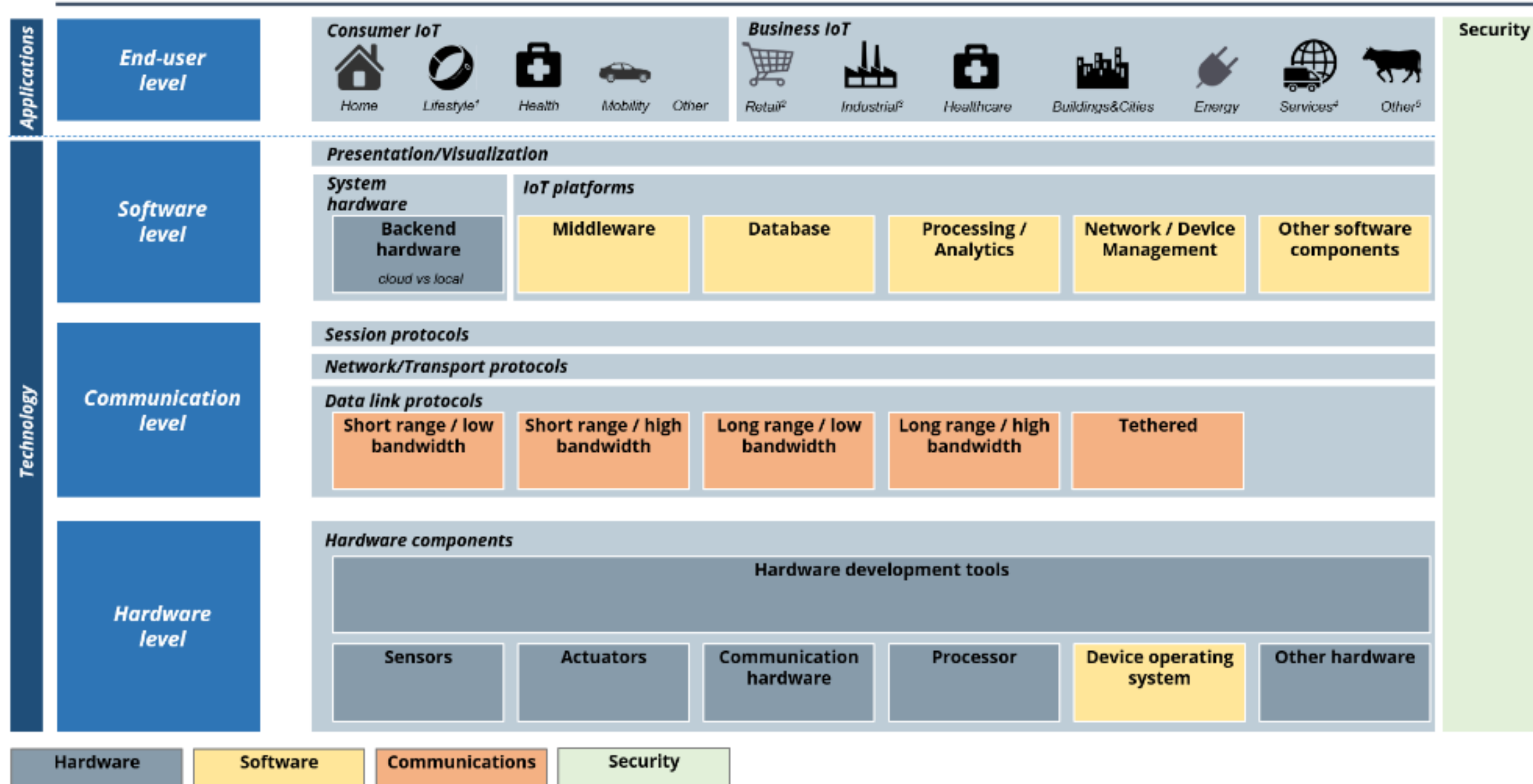
数字信号/逻辑处理

FPGA - 数字世界的“乐高积木”

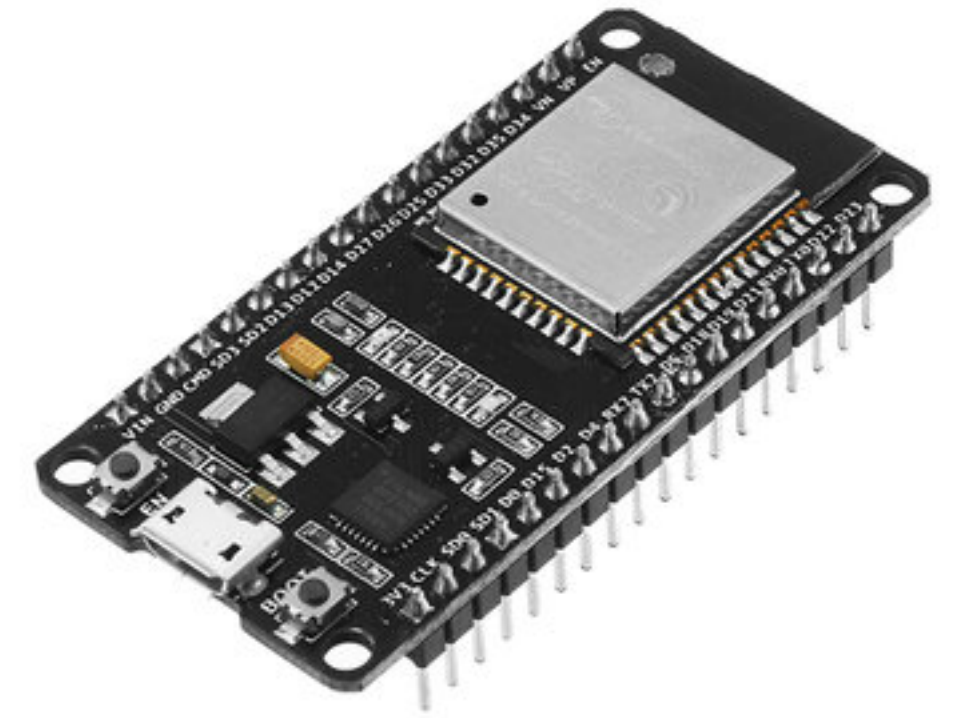


微处理器/微控制器：智能硬件/物联网产品的核心

Internet of Things - Technology architecture



1. Lifestyle incl Quantified-self products 2. Incl all other B2B commercial IoT 3. Industrial goods business 4. Services incl. finance and insurance 5. Other including education, public and military, media, telecom,
 Note: Product, image, or service names are the property of the respective owners
 Source: www.IoT-Analytics.com 2015

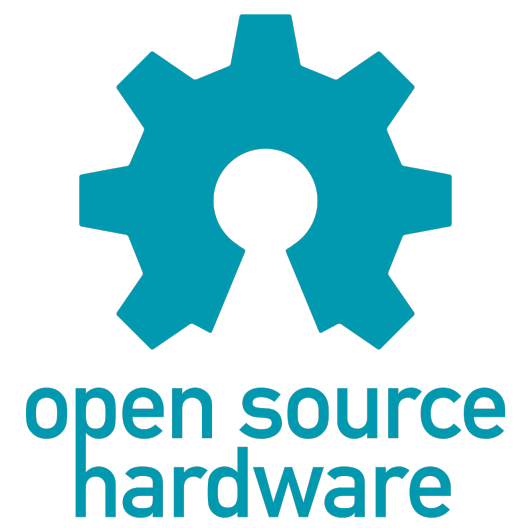


网络通信

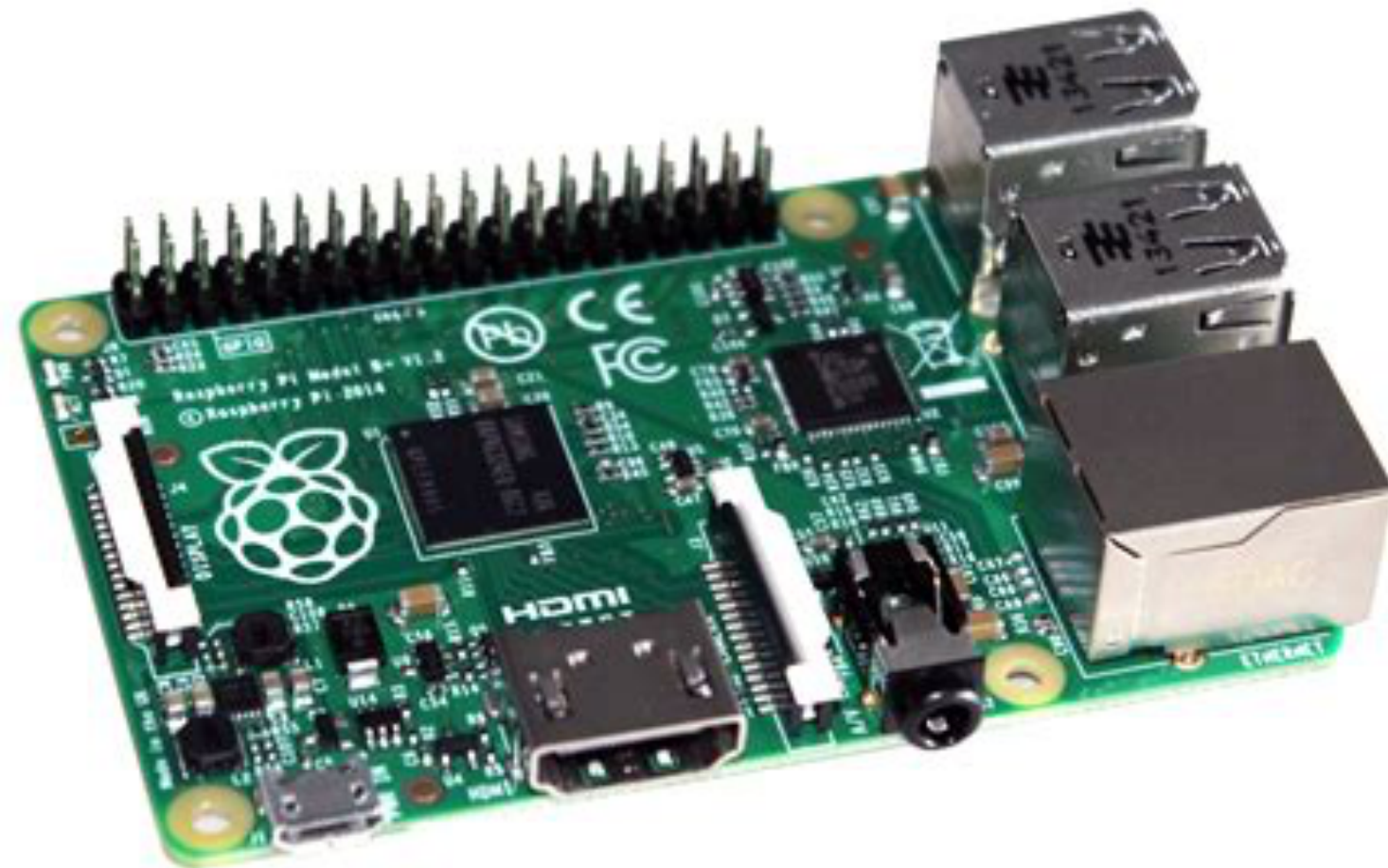
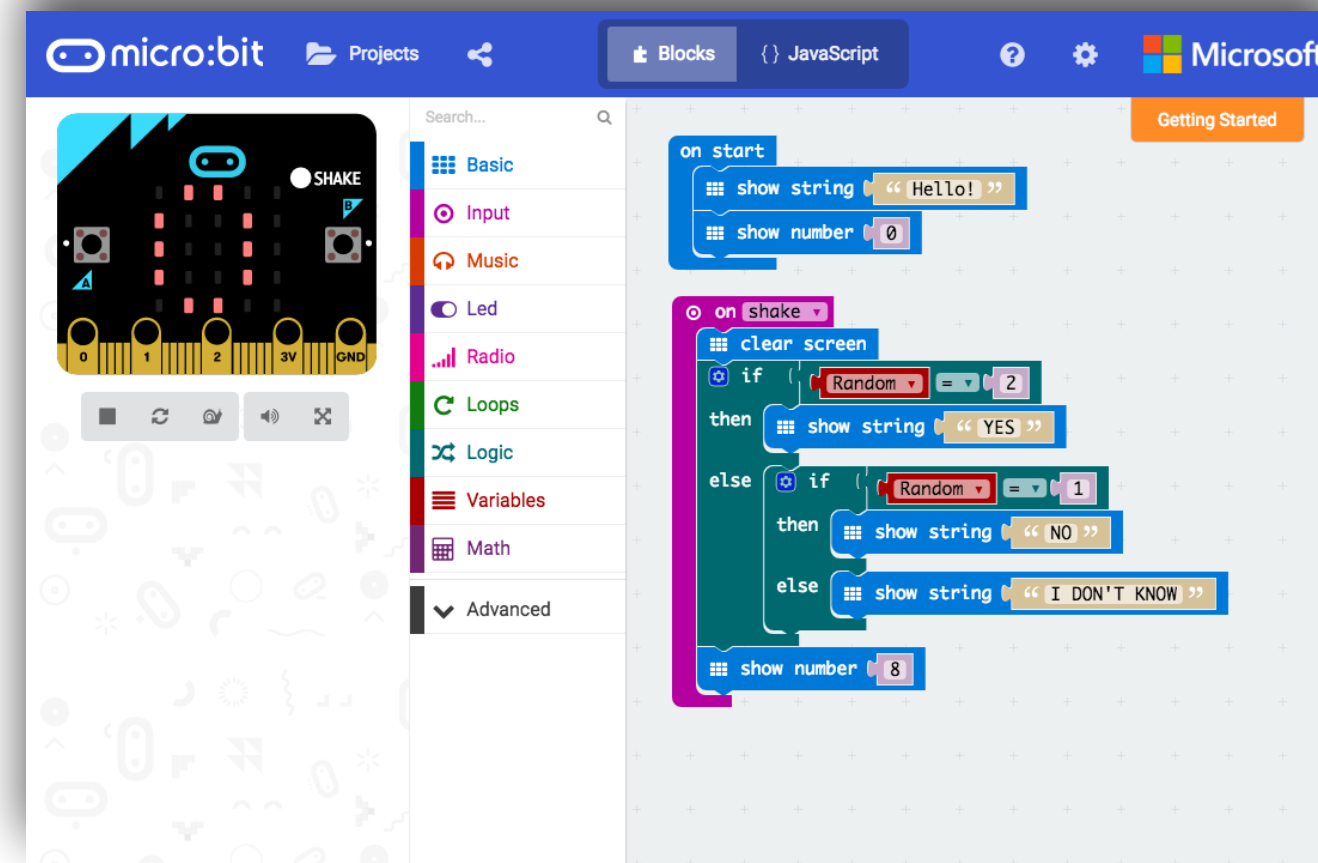
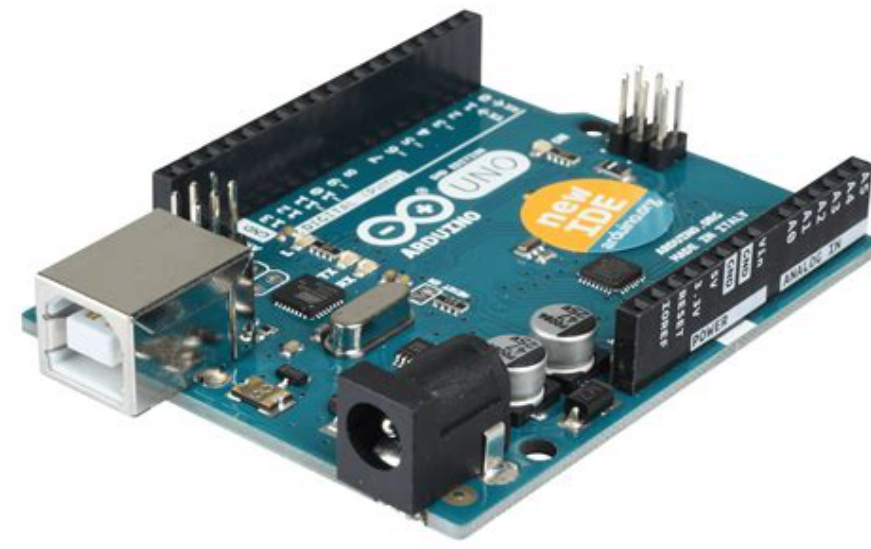
连接

各部分的核心参数

电路	关键参数
电源	电压、负载能力、纹波、效率
传感器	灵敏度、接口方式
模拟链路	幅度、频带
A/D、D/A	转换率、分辨率、SFDR、接口方式
数字信号处理/FPGA	逻辑资源、存储资源、IO、速度
MPU/MCU	速度、接口、内部资源、开发环境
网络通信	通信方式、速率、接口、协议



开源平台 - 大大降低了硬件学习的难度和成本



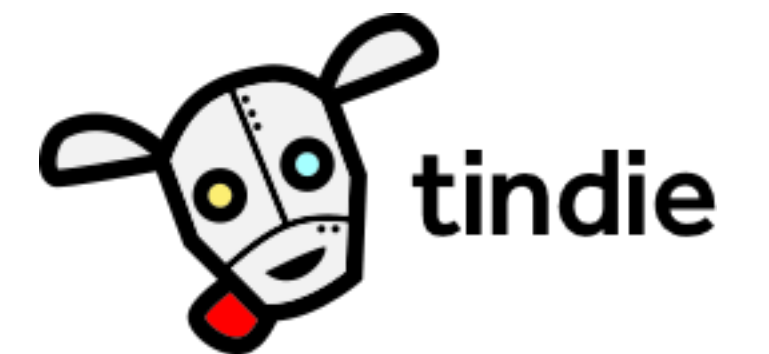
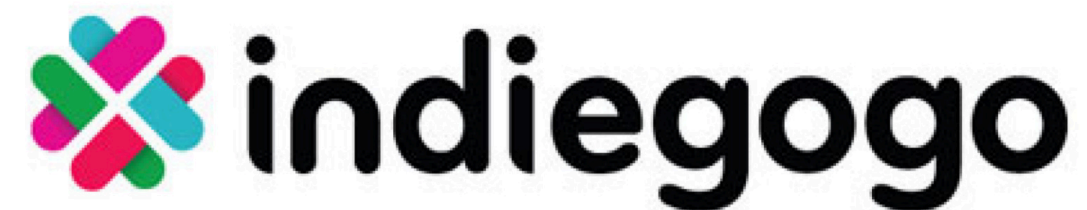
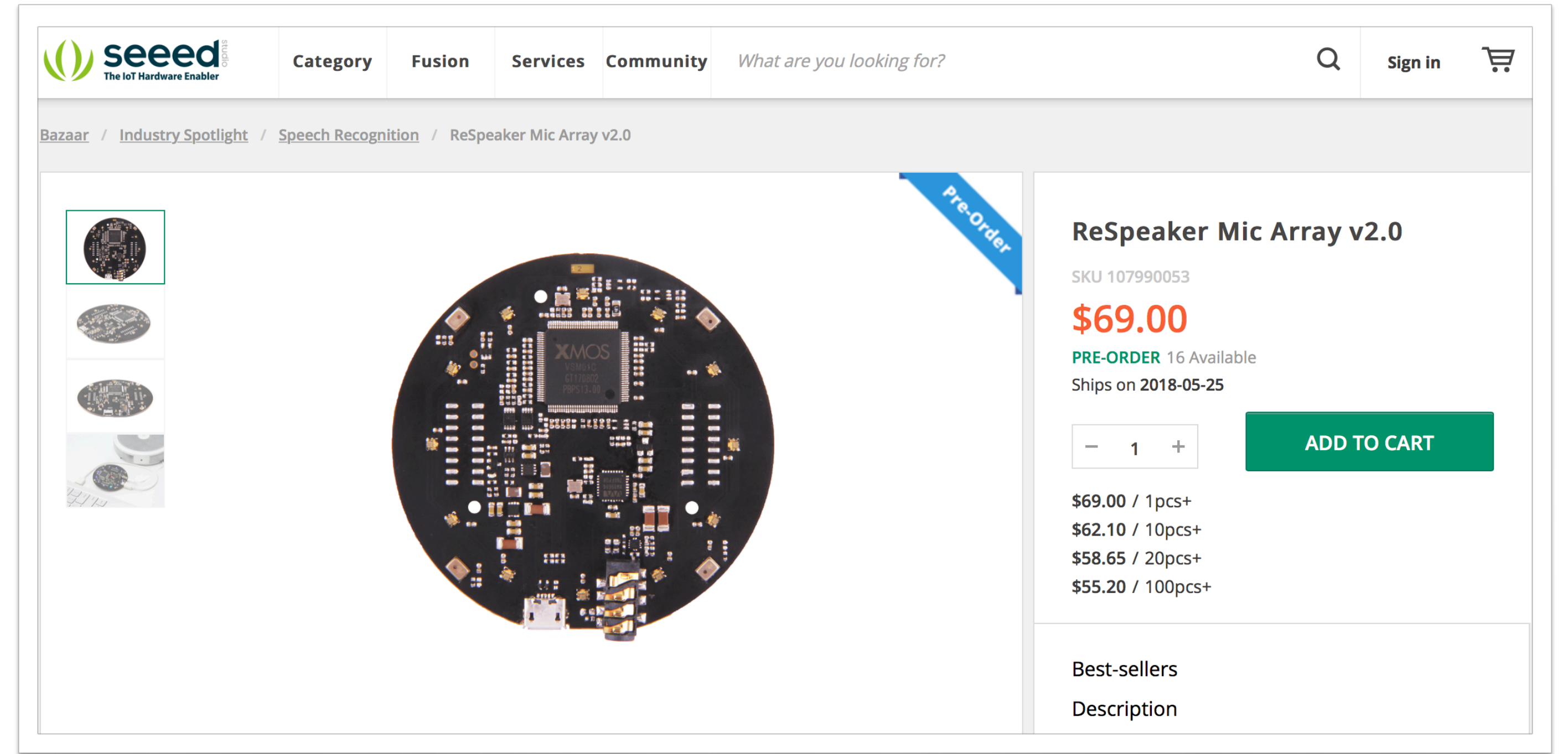
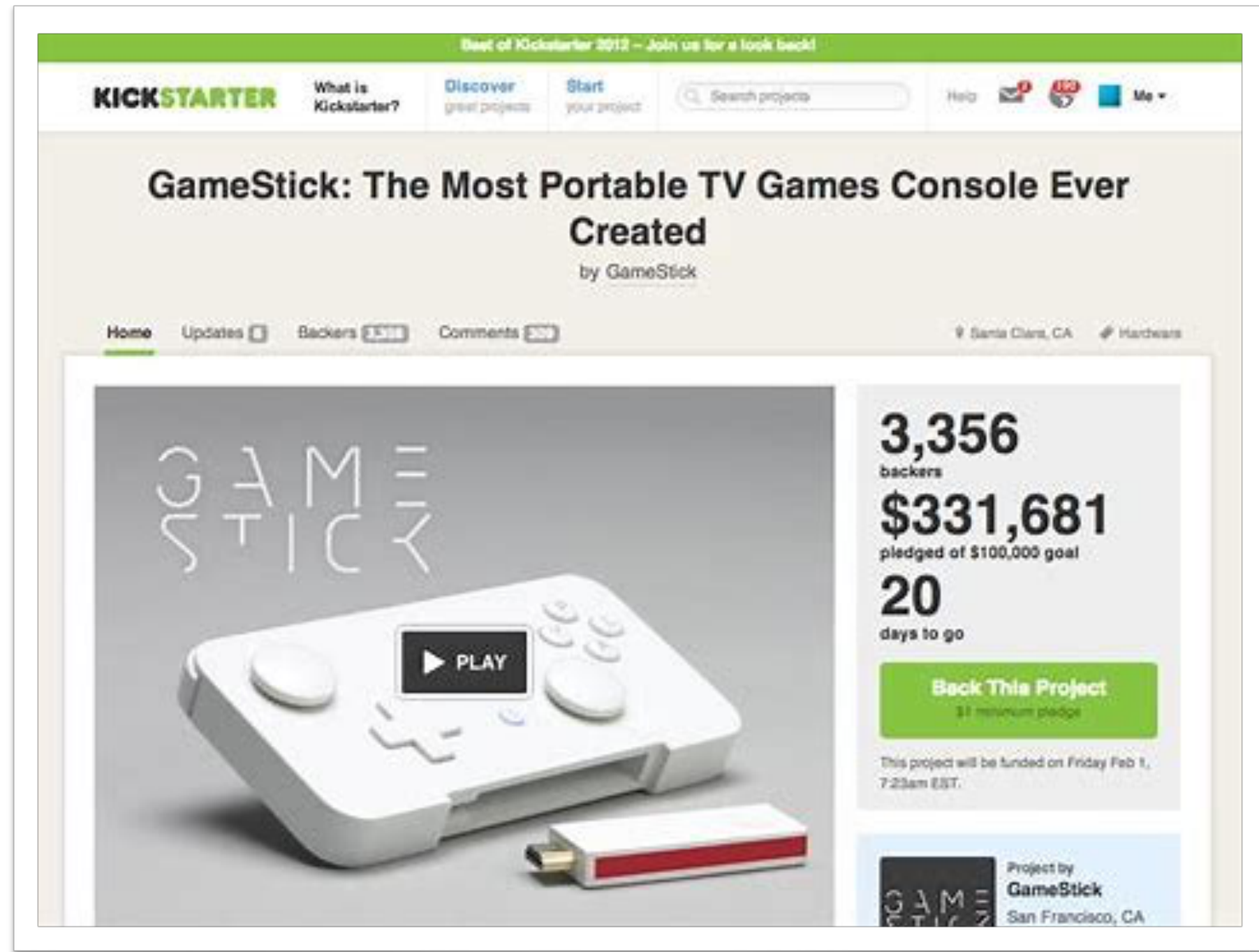
小脚丫

颠覆性的开源FPGA板。

特性：
最小尺寸，仅拇指大小
易于使用，板载编程器
适合学习，搭载丰富外设
用于开发，灵活扩展

CIRMALL
电路城

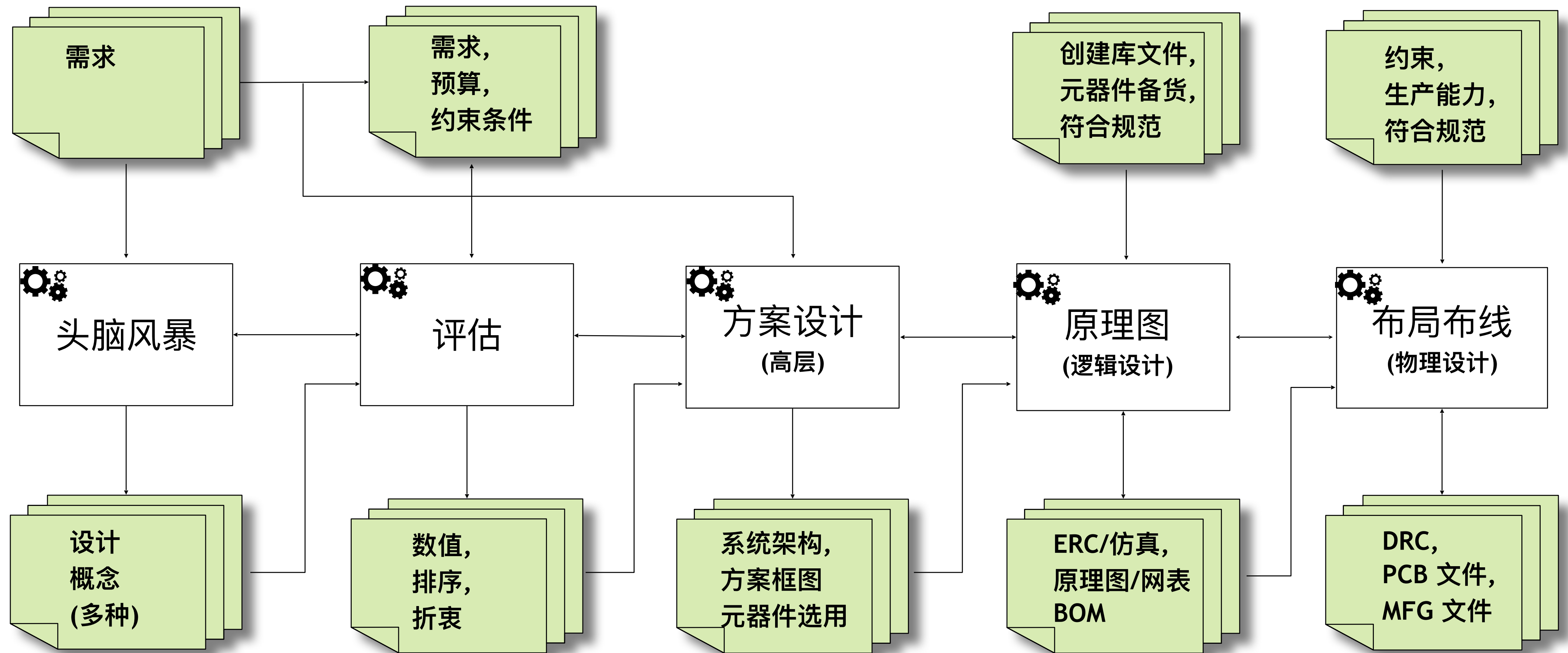
众筹 - 快速推向市场和概念验证



各部分的核心参数

电路	关键参数
电源	电压、负载能力、纹波、效率
传感器	灵敏度、接口方式
模拟链路	幅度、频带
A/D、D/A	转换率、分辨率、SFDR、接口方式
数字信号处理/FPGA	逻辑资源、存储资源、IO、速度
MPU/MCU	速度、接口、内部资源、开发环境
网络通信	通信方式、速率、接口、协议

产品设计流程 - 规范化、时间节点



*通过模型、原型样机、讨论进行评估

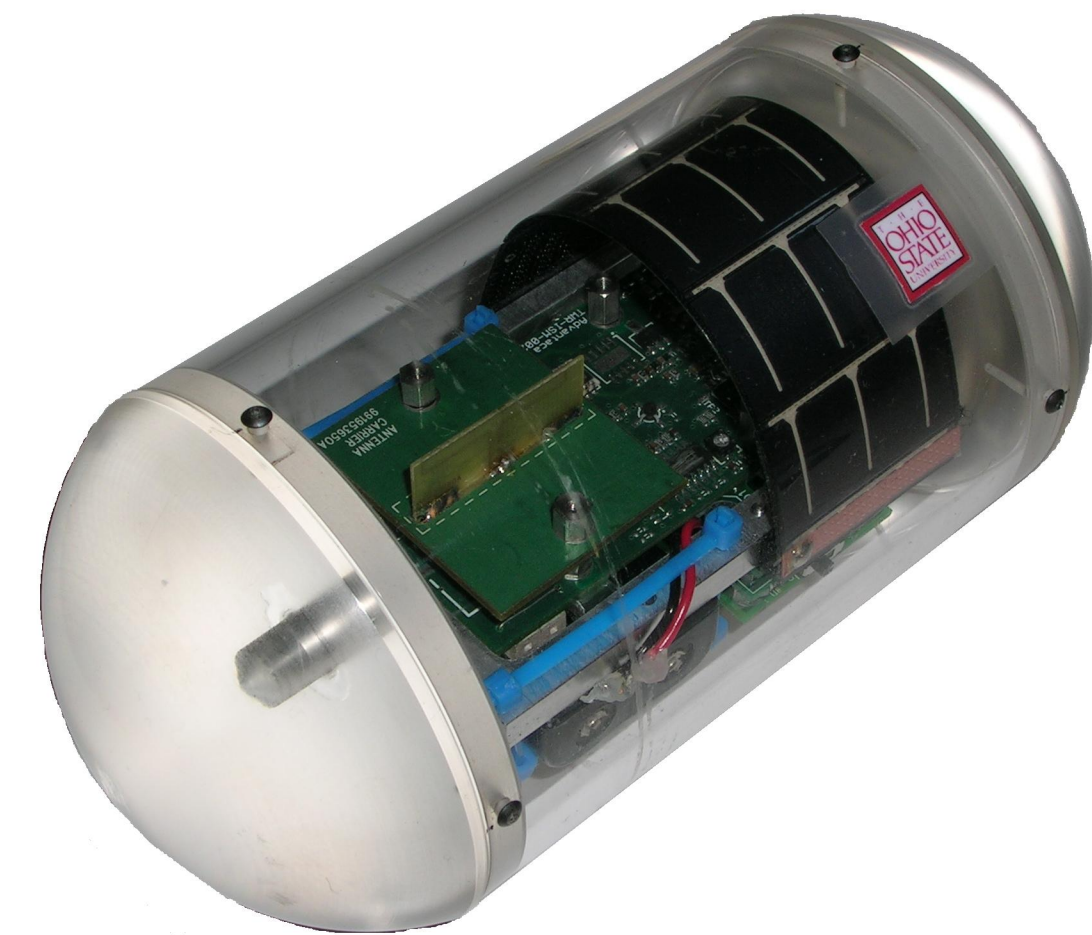
设计流程本质上是一个将概念变成实际的、能够工作的系统的过程

创意
(概念)

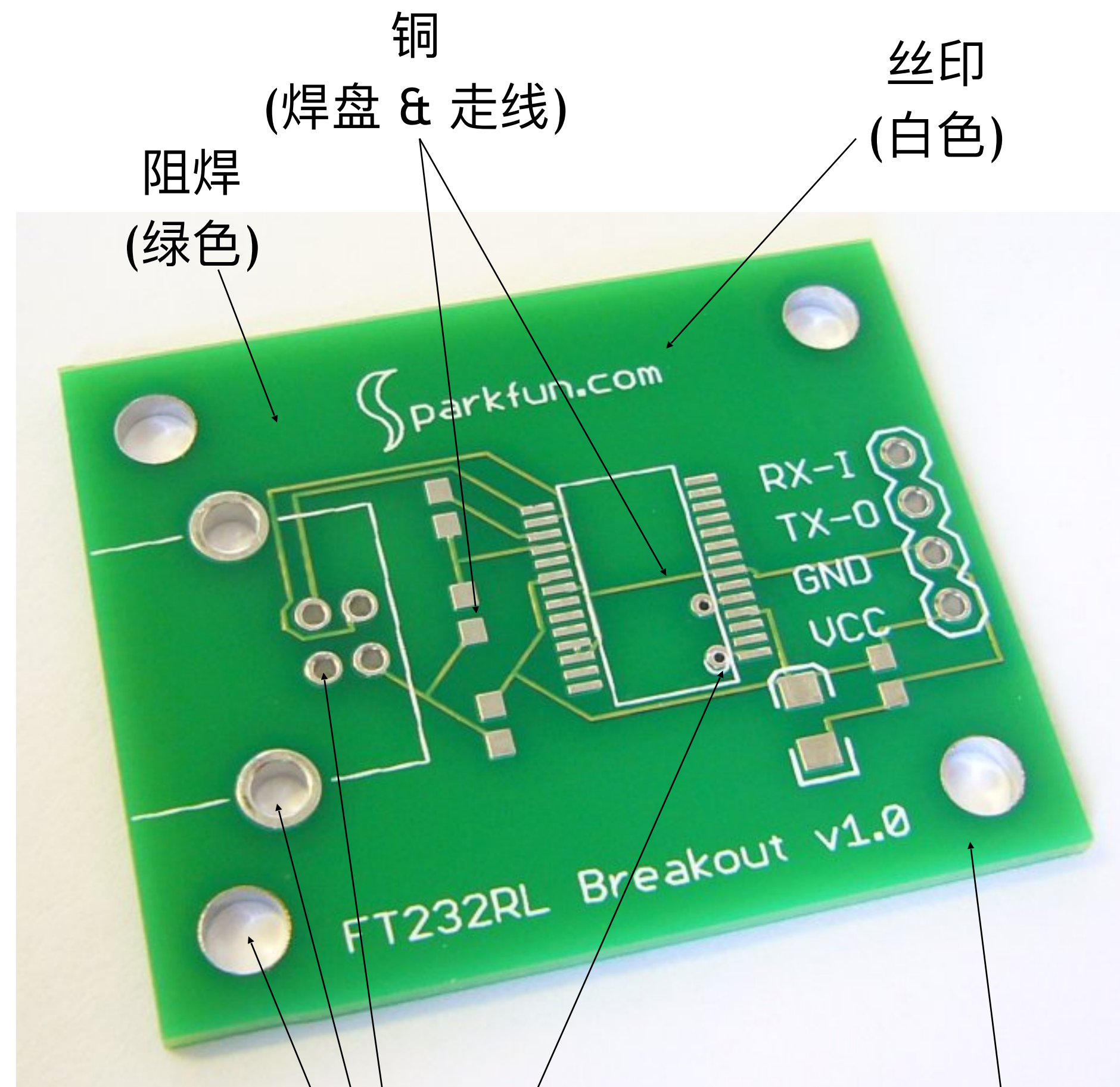
“一个可以空投式运动传感器 - 检测范围为10米，能使用6个月”



实施
(能够工作的系统)

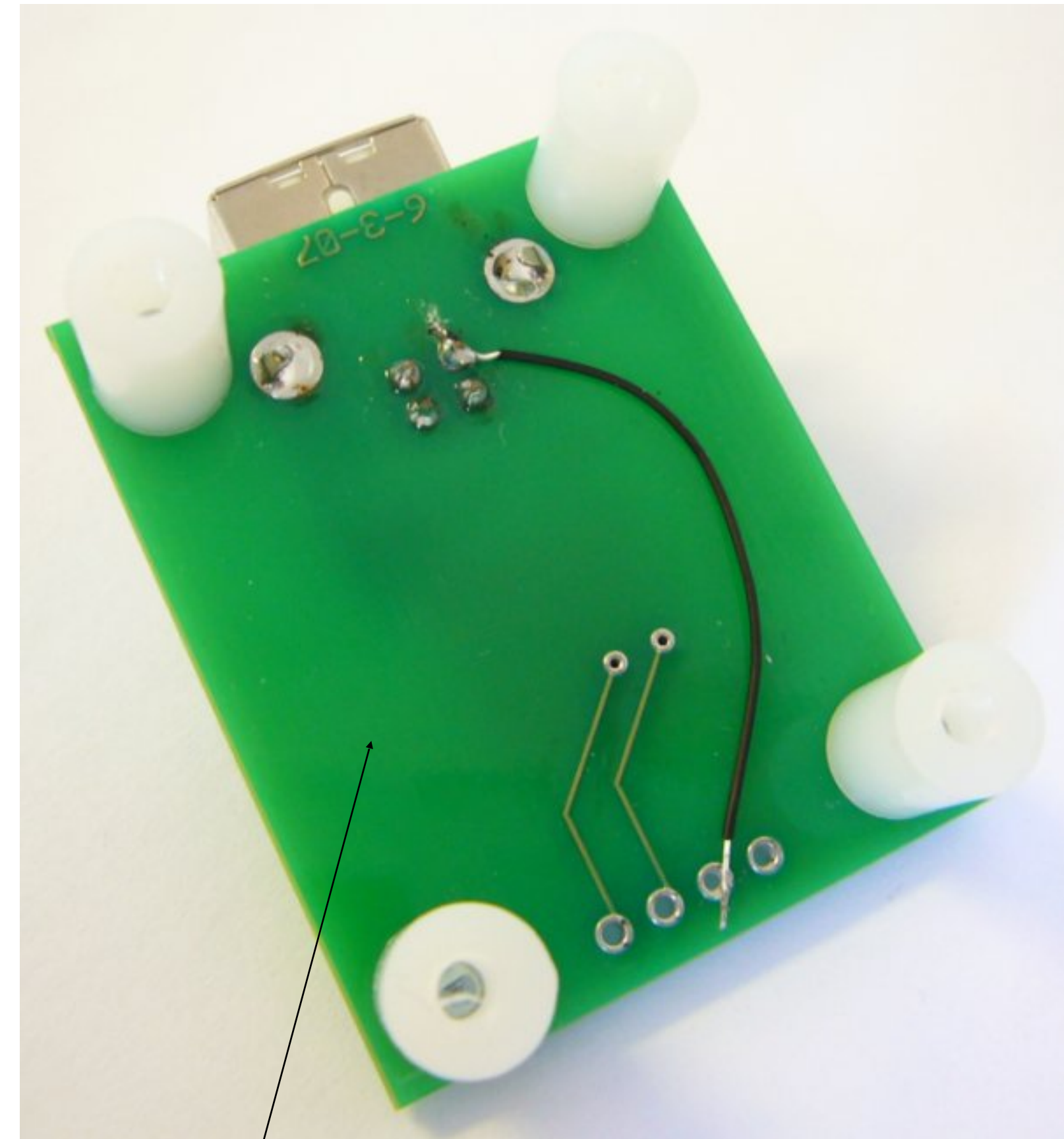


最终的目标是一个PCB板



钻孔文件
(大小以及 x-y 坐标)

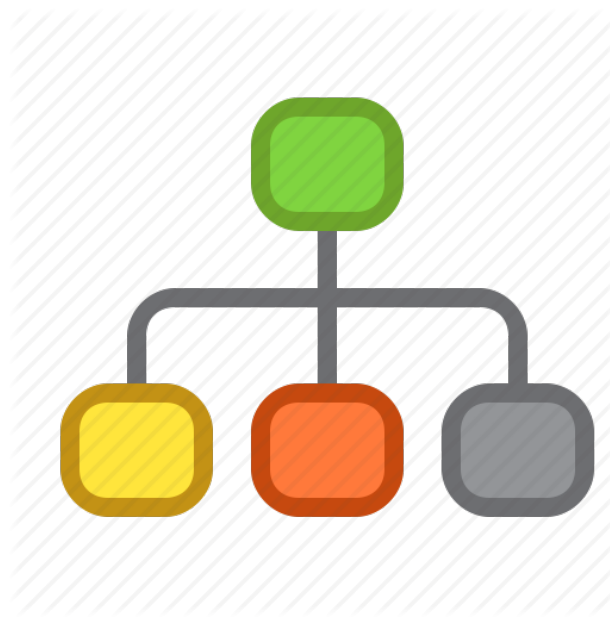
顶层



底层

头脑风暴

- 目标：越多的主意/方案越好
- 最好多人参与讨论，集思广益
- 根据需求，但不要受约束或正式需求的限制

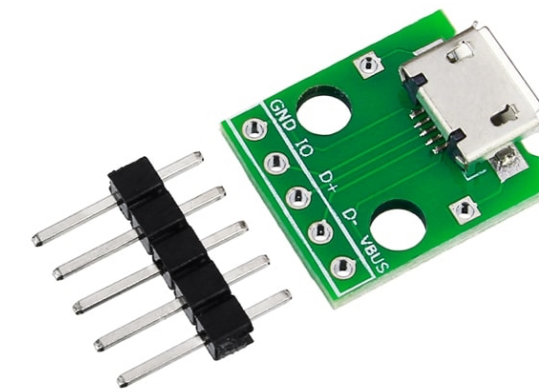


框图/草稿



元器件

- 无源器件：0805、0603等
- IC封装：QFN、TQFP、BGA等
- 库



连接方式

- 机械连接
- 总线连接
- PC连接



供电和性能

- 功率要求
- 电池性能
- 高速/高灵敏度

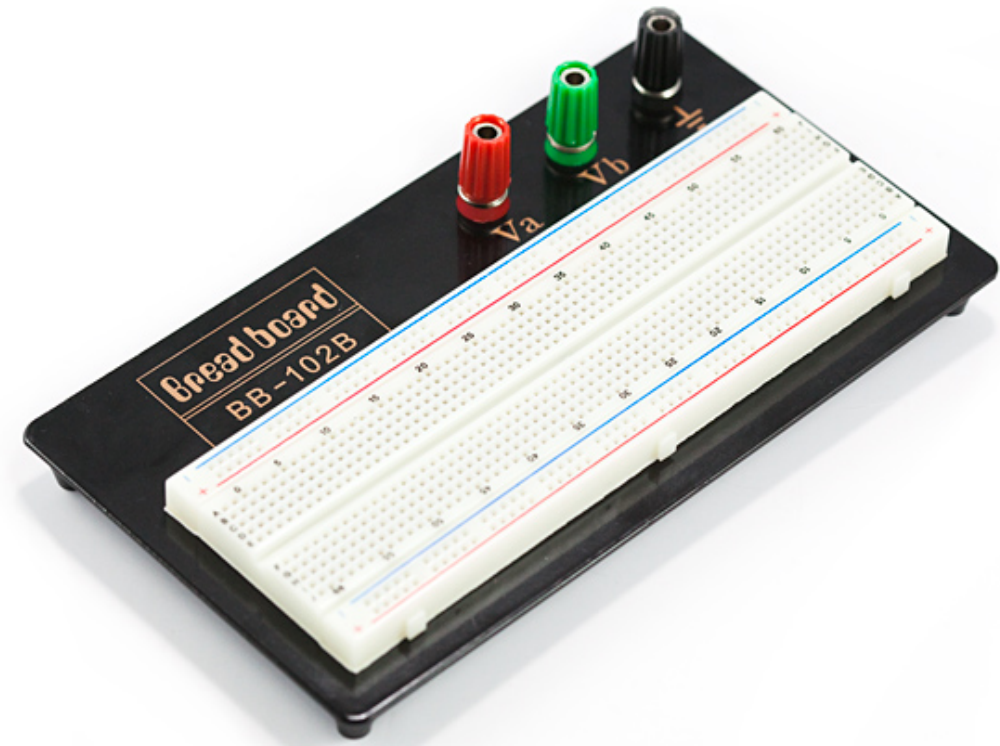
评估

- 目标：选出最佳的方案
- 用“需求”和“限制”来进行评估
- 同时考虑到：
 - 上市时间
 - 性价比 - 开发成本/单价
 - 熟悉程度
 - 备用方案

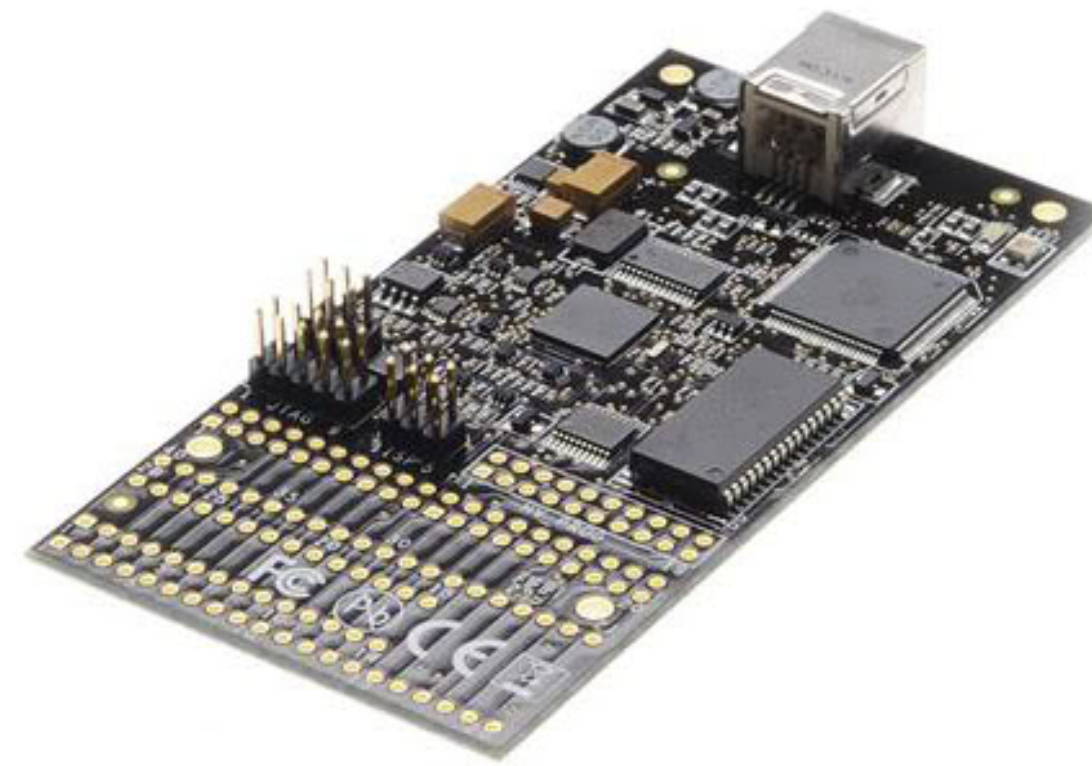
满足项目的需求：

- 功能
- 性能
- 可用性
- 可靠性
- 可维护性
- 预算

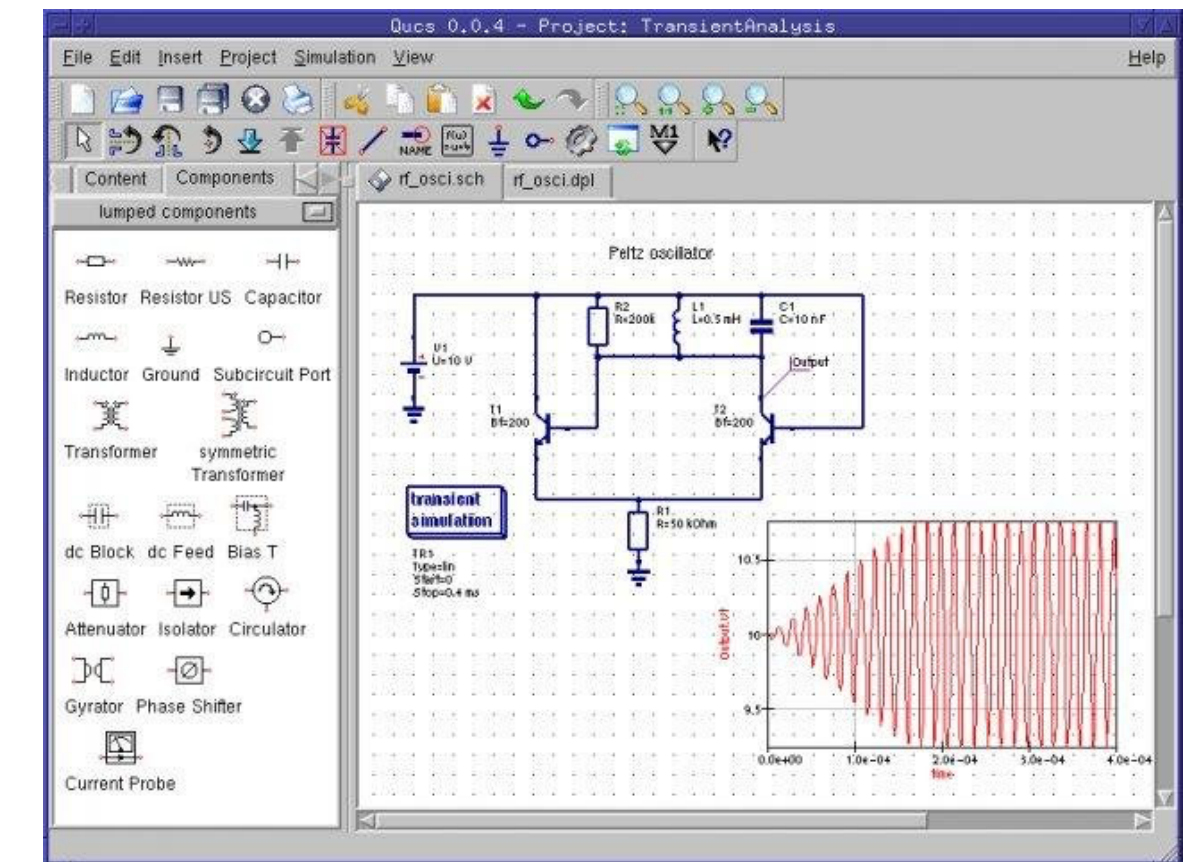
电路测试评估



面包板



开发板



仿真