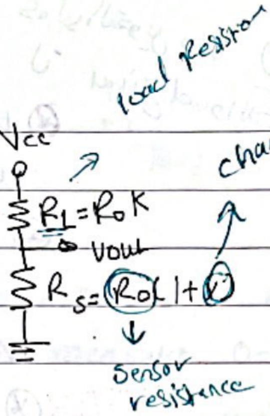
Ac & DC Bridges.

* Voltage divider



$$V_{out} = V_{cc}\left[\frac{R_0(1+x)}{R_0(1+x)+R_0K}\right]$$

$$V_{out} = V_{cc}\frac{(1+x)}{1+x+K}$$

what is the Sensitivity ?

⇒ derivative

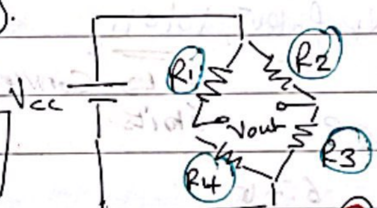
$$\frac{d}{dx}\left[\frac{V_{cc}(1+x)}{1+x+K}\right]$$

$$= V_{cc}\frac{K}{(1+x+K)^2}$$ → The sensitivity.

* what is the Value of R_L to acheive max sensitivity?

$\frac{ds}{dK} = 0 \Rightarrow K = 1+x$, so when $R_s = R_L$

* wheatstone bridge (DC).



$R_3 = R_0(1+x)$

Deflection mode

$$V_{out} = V_{cc}\left[\frac{R_3}{R_3+R_2} - \frac{R_4}{R_4+R_1}\right]$$

null mode

$V_{out} = 0 \Rightarrow R_3 = R_4\frac{R_2}{R_1}$

$$K = \frac{R_1}{R_4} = \frac{R_2}{R_0}$$

$$V_{out} = V_{cc}\frac{Kx}{(1+K)(1+K+x)}$$

* Wheatstone bridge is used when change of x is small.

* null mode ⇒ used with measurements is independent of V_{cc}

The sensitivity of wheatstone bridge ? $\frac{dV_{out}}{dx}$

⇒ $V_{cc}\frac{K}{(1+x+K)^2}$ → the sames as voltage divider

* Ac bridges.

⇒ wheatstone bridges Can be used to Calculate inductance & Capacitance

⇒ Balance → $\frac{Z_1}{Z_4} = \frac{Z_2}{Z_3}$ → real & imaginary part $[R+jX]$ each one of them

$$R_1R_3 - X_1X_3 = R_4R_2 - X_4X_2$$

important

DAC & ADC ⇒ analog كمان التحويل من digital لـ و العكس

in arduino
- B ⇒ Binary (8 bits)
- O ⇒ Octal
- no ⇒ decimal
- 0x ⇒ hexa decimal

- usually natural binary coding is used
- Digital code consist of n bits.
  b_{N-1} ..... b_0
  MSB ← b_{N-1}, b_0 → LSB
- fractions.
  Range : $0 \to (1-2^{-N})$. when N is the # of bits.
  Precision : 2^{-N}

ADC

ADC ⟷ DAC

- $V_{analog\,(in)} = \frac{N_{10}}{2^N} \times V_{ref}$ ⇐ This formula can be used for Both DAC & ADC

* مثلاً لو كان عنا رقم ديجتال كالتالي : ← Vref = 10V, 101011_2 ↓ 6 bits. ↳ Convert this to decimal. 43_{10}

Vref for DAC = 10V

what is the analog value?

$V_{analog} = \frac{43}{2^6} \times 10 = 6.7V$

* لو كان السؤال العكس يعني إدعطنا فيه analoge ولازم نجد لنا digital Representation إلها!

ADC

6.7V = Vanalog مثلاً نفرض
bits are 6 bits.
Vref = 10

$N_{10} = 2^N \cdot \frac{V_{analog}}{V_{ref}}$

$INT(N_{10}) = 2^6 \cdot \frac{6.7}{10} \approx 43$
42.8
↓
101010 ← 42
↳ so we have an error

يا صغر الفرق بين الحالتين
Resolution of one bit.

- $\Delta V = \frac{V_{ref}}{2^n}$ ⇒ بوصفنا مقدار الايرور.
  ↓
  Resolution

@ كلما كان الرقم أصغر كل ما كان, clearly, the resolution of ADC or DAC

احسن ما كانت ال ADC او ال DAC لعن نحلي ال Resolution تأثيم منيح سو لازم نعمل؟
↳ * اما بنزيد عدد ال n of bits او بنقلل ال ref voltage (Vref).

about Arduino: It's clear that the arduino have both ADC & DAC
↓ at input — ↓ at output

* لازم تكون عارفين عدد ال Bits تاع كل واحد فيهم !
They are not the same (The # of bits differ).

=D Example

Temprature is to be measured by a sensor wit an output of 0.02 V/C. Determine required ADC (Reference, word size) to measure 0-100C with 0.1 Resolution.
↳ # of bits

فيه Temp sensor بقيس ل 100 ← 0
دال Resolution إله 0.1C degree

البدنا ADC اللي ممكن نختاره ويعطي 0.1 Resolution ؟
→ Range 0-100 with increment 0.1

So we need $\frac{100}{0.1}$ change → 1000 change =D [10 bits] → # of bits).

0.02 V/C * 100 C → 2V (V ref)
↳ must be 2V + increment of resolution for ADC

Resolution = $\frac{V_{ref}}{2^N}$ → Bits.
* الفكرة الاساسية اذا عرفنا منه ال Vref بنقدر نعرف عدد ال Bits.

A 0.1C resolution results in 0.1 * 0.02 = 2mV

$2mV = \frac{2}{2^{n}}$ =D $2^n = 1000$ $\boxed{n = 10 \text{ bits}}$

أو من خلال القوانين اللي موجودة.

* What is the maximum input that we can put at [ADC] ?

هل ال Vref هي الحد، لا لازم أقل! منطقياً لازم تكون أقل ب Step من Vref

So Vmax لازم تكون أقل ب Step واحد من Vref
So the answer is Vref - resolution of 1 bit

$V_{min} = 0$, $V_{max} = V_{ref}\left(\frac{2^N - 1}{2^N}\right)$

مجموعة

$Q \text{ (Step size)} = \frac{V_{full\,scale}}{2^N - 1}$ or $\frac{V_{ref}}{2^N}$

Q
Step size = $\frac{V_{max} - V_{min}}{\# \text{ of levels}}$

• $V_{full\,scale} = V_{max} - V_{min}$
↳ $= V_{ref}$

بالكتاب ← Res

Res = $\frac{V_{full\,scale}}{2^N}$
↳ Q or Δ

هاي اللي مقصود فيها.

Quantization error range
↳ $\left[-\frac{\Delta}{2}, \frac{\Delta}{2}\right]$

Unipolar & Bipolar

① Unipolar

$$V_{analog} = \frac{N_{10}}{2^n} \cdot V_{ref} \leftarrow DAC \quad , \quad INT[N_{10}] = \frac{V_{analog} \cdot 2^n}{V_{ref}} \leftarrow ADC$$

② Bipolar

$$V_{analog} = \frac{N_{10}}{2^n} \cdot V_{ref} - \frac{V_{ref}}{2} \rightarrow DAC$$

$$INT(N_{10}) = \frac{\left[V_{analog} + \frac{V_{ref}}{2}\right] \times 2^n}{V_{ref}} \rightarrow ADC$$

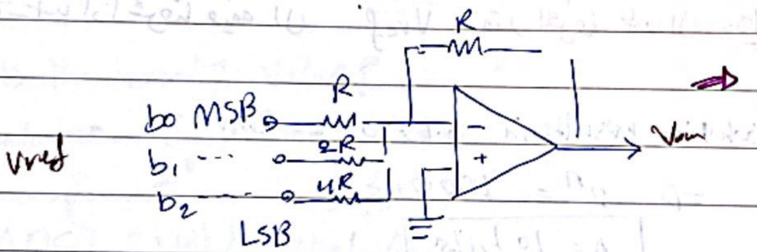
* لما كان Vmax عبارة عن Vref بطلع step واحدة

ADC ⇒ is exactly the same process of DAC

Now, How to realize operation of DAC & ADC?

كيف ممكن ده الواقع نوجد دارة الكتروني لتنفيذ عمليات ال DAC & ADC

*

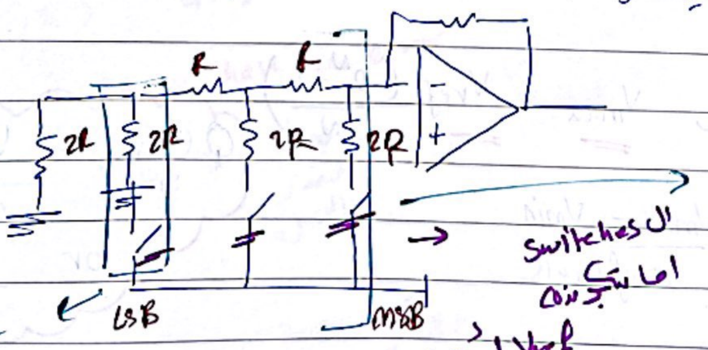


⇒ Have a problem with resistances.

$$V_{out} = \left[b_0 + \frac{b_1}{2} + \frac{b_2}{2^2}\right] \cdot V_{ref}$$

$$V_{out} = \frac{N_{10}}{2^n} \cdot V_{ref} \Leftarrow \underline{DAC} \text{ (Digital to analog)}.$$

لكن هاي الدارة فيها مشاكل بالتالي في دارة جديده اسمها R2R Ladder

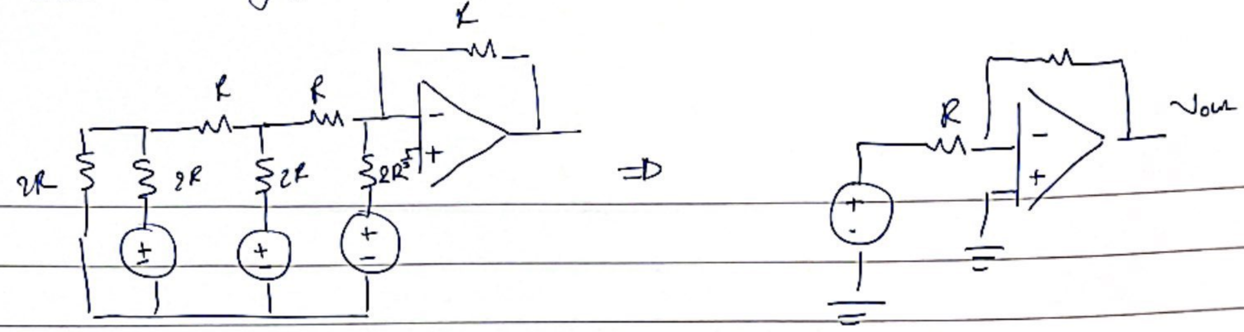


→ Thevenin.

→ ال switches اما بتكون 0 (ground) او Vref

← each one of these branches is bit

The circuit become as follow:



So that $V_{out} = \frac{N_{10}}{2^N} \cdot V_{ref}$

PWM

الفكرة الأساسية: التغيير عند ال signal لل width

Generating a pulse signal, width of this pulse proportional to amplitude

بالتالي كل ما زاد ال width , كل ما ال amplitude لل signal كان أكبر , والعكس صحيح

So, the signal is represented rather than its amplitude and its width.

PWM it is a technique that we could use in order to generate analog value proportional to its input

How to convert PWM to analog?
↳ using Low pass filter

Duty cycle = $\frac{T_{on}}{T}$, 0 → 100% , Frequency = $\frac{1}{T}$ rad/sec

How PWM signal is DC?

DAC → output بيعطيني analog

بالتالي كيف بنقرأ ال output من ال PWM ؟