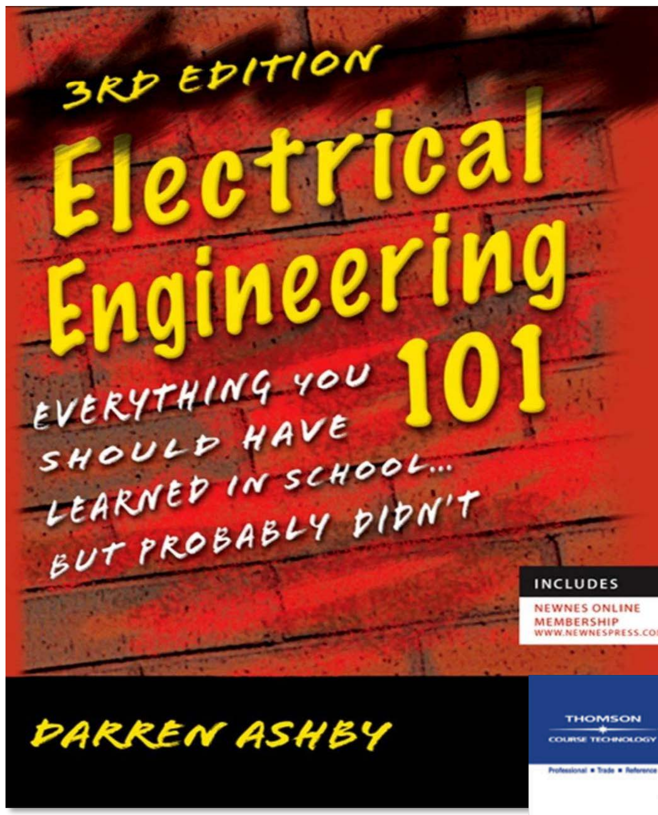
Électronique pour l’IHM

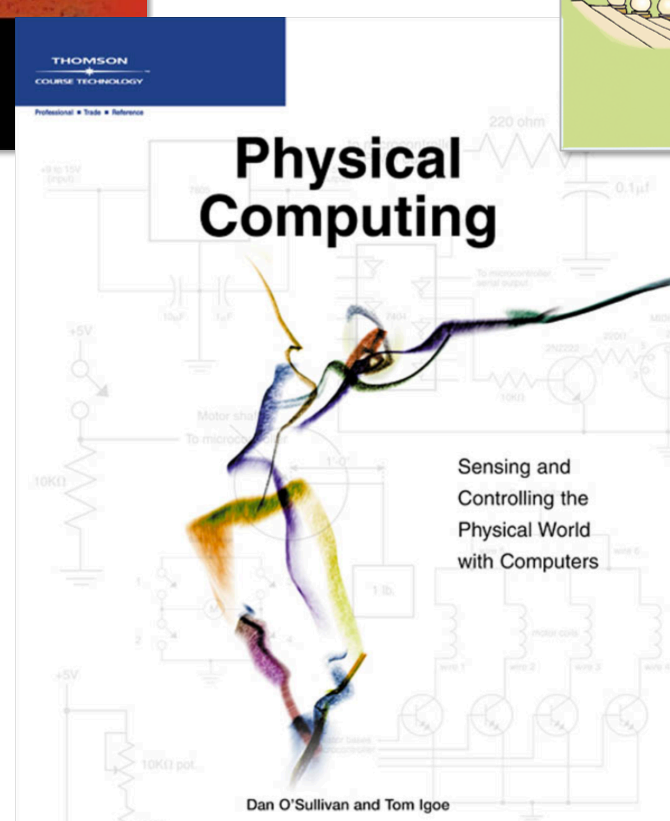
Thomas Pietrzak
Master 2 Informatique — RVA

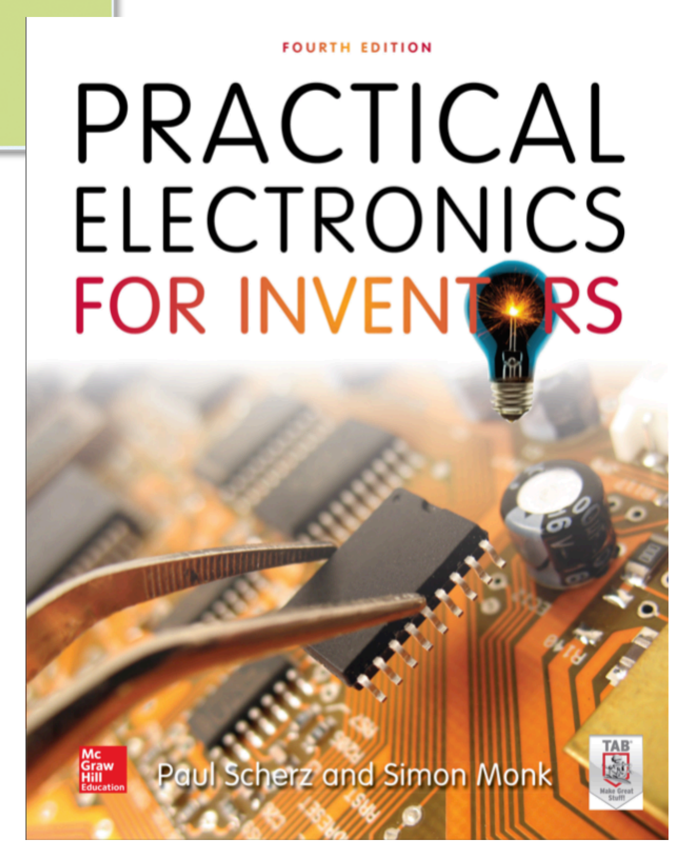
Université de Lille

Lecture

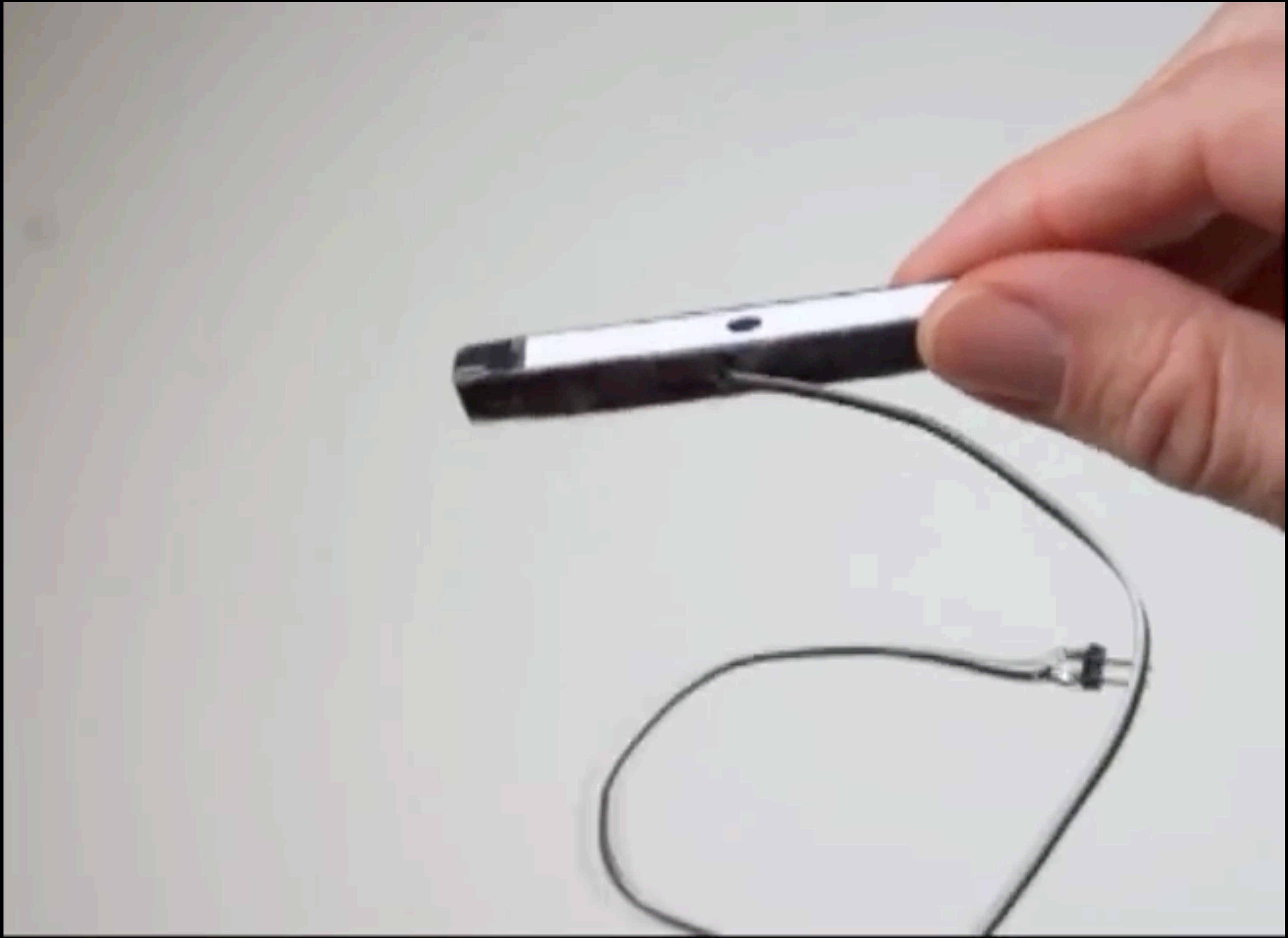

3RD EDITION
Electrical Engineering 101
EVERYTHING YOU SHOULD HAVE LEARNED IN SCHOOL... BUT PROBABLY DIDN'T
INCLUDES
NEWNES ONLINE MEMBERSHIP
DARREN ASHBY


Jean-Pierre Petit
L'AMBRE ET LE VERRE
Histoire de l'électricité
Cette électricité est vraiment dénuée du moindre intérêt. Un amusement de salon, tout au plus. Ça n'a aucun avenir, si vous voulez mon avis.
édité par l'association Science et Culture pour tous

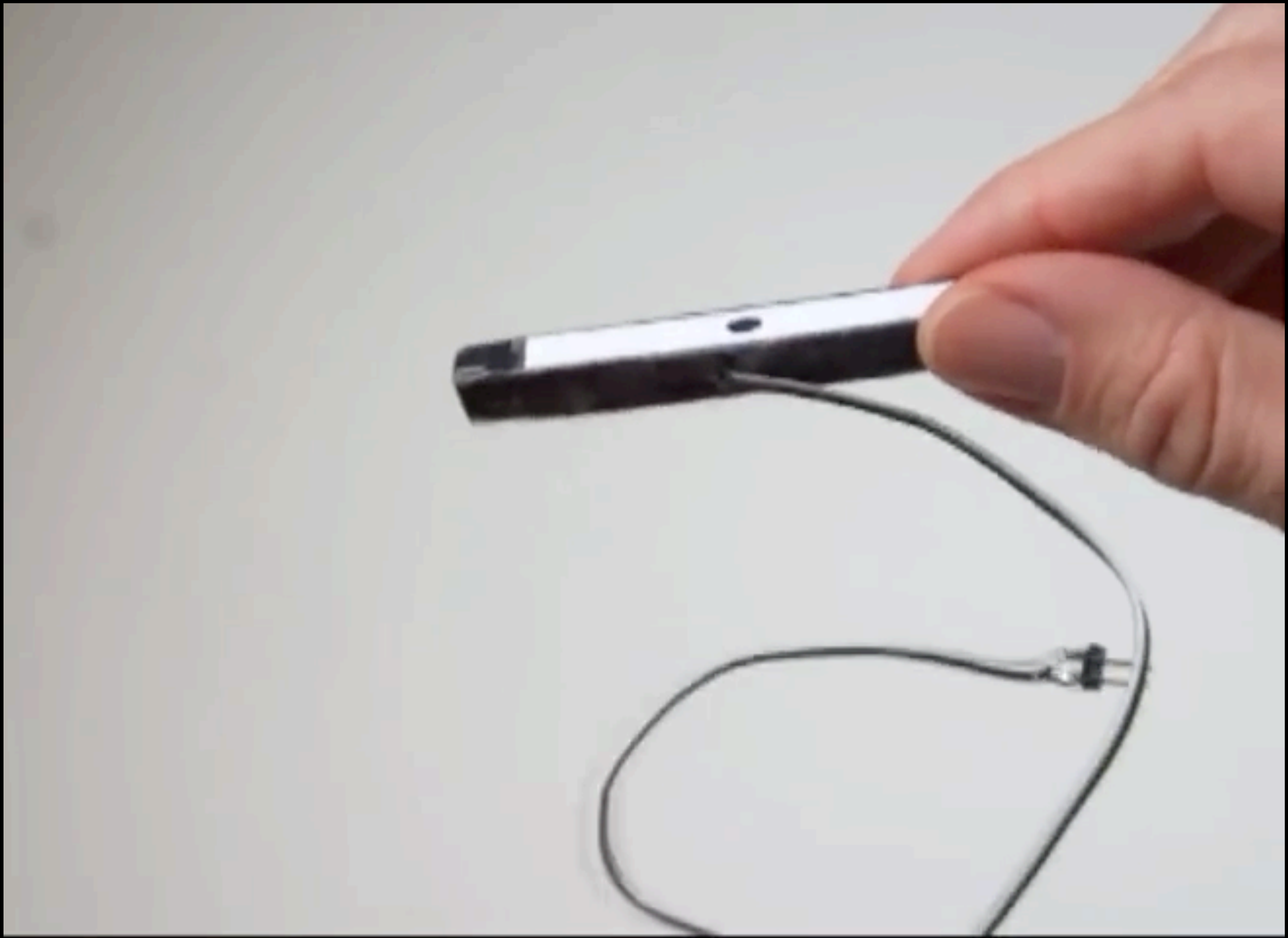

THOMSON
Physical Computing
Sensing and Controlling the Physical World with Computers
Dan O'Sullivan and Tom Igoe


FOURTH EDITION
PRACTICAL ELECTRONICS FOR INVENTORS
Paul Scherz and Simon Monk


Logitech



Conté (Univ. Lille, Univ. Waterloo, 2011)



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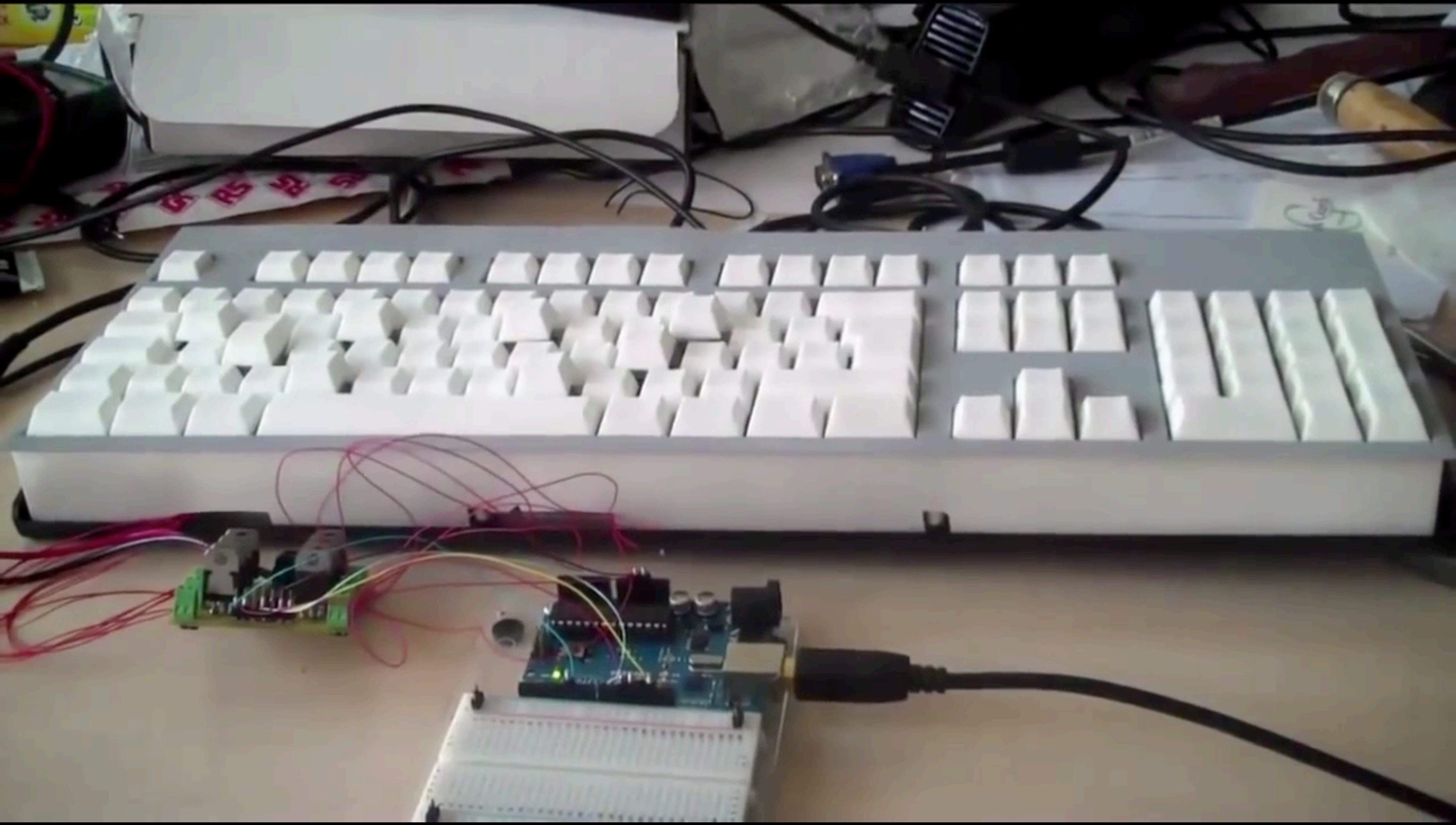
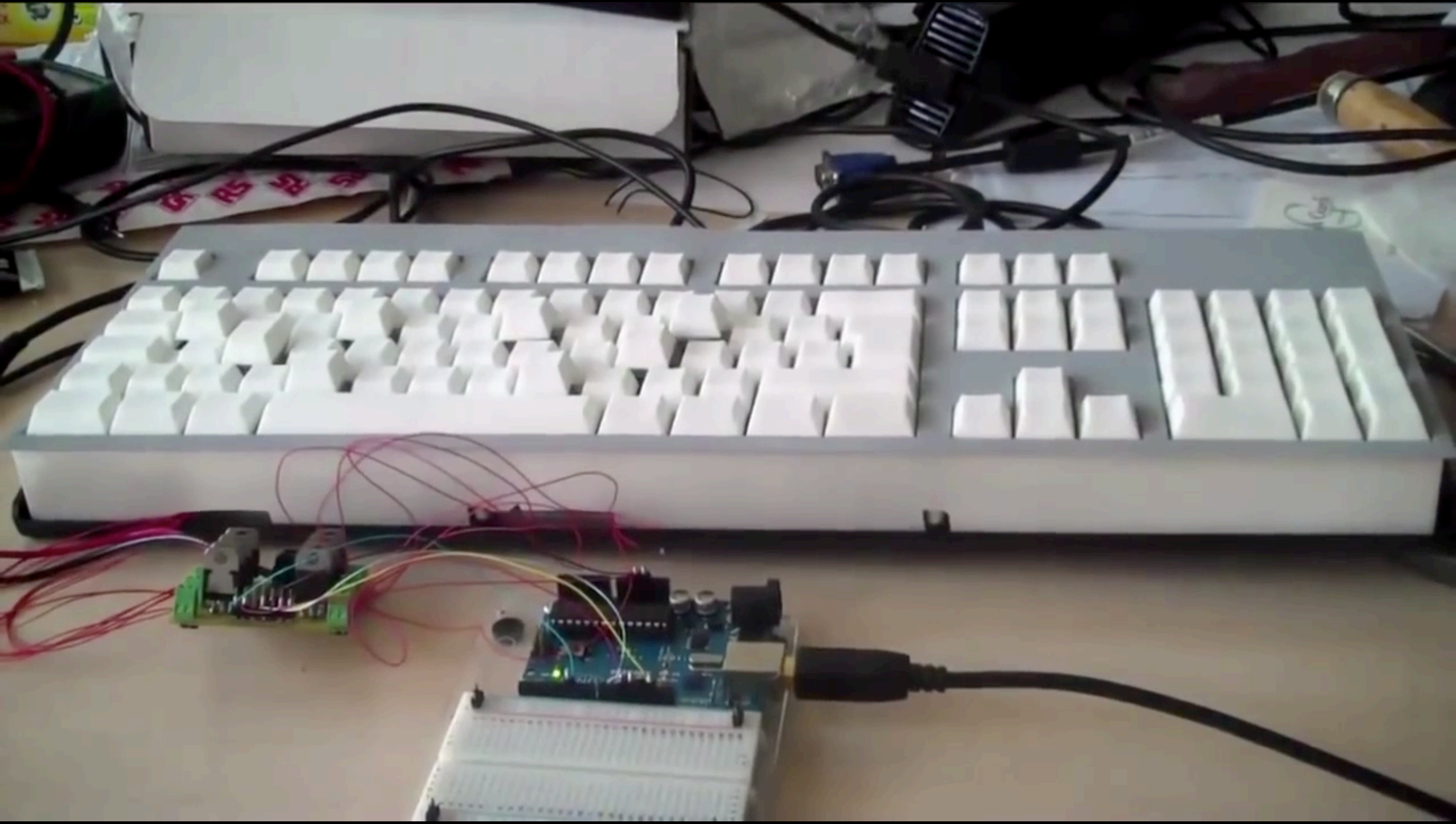
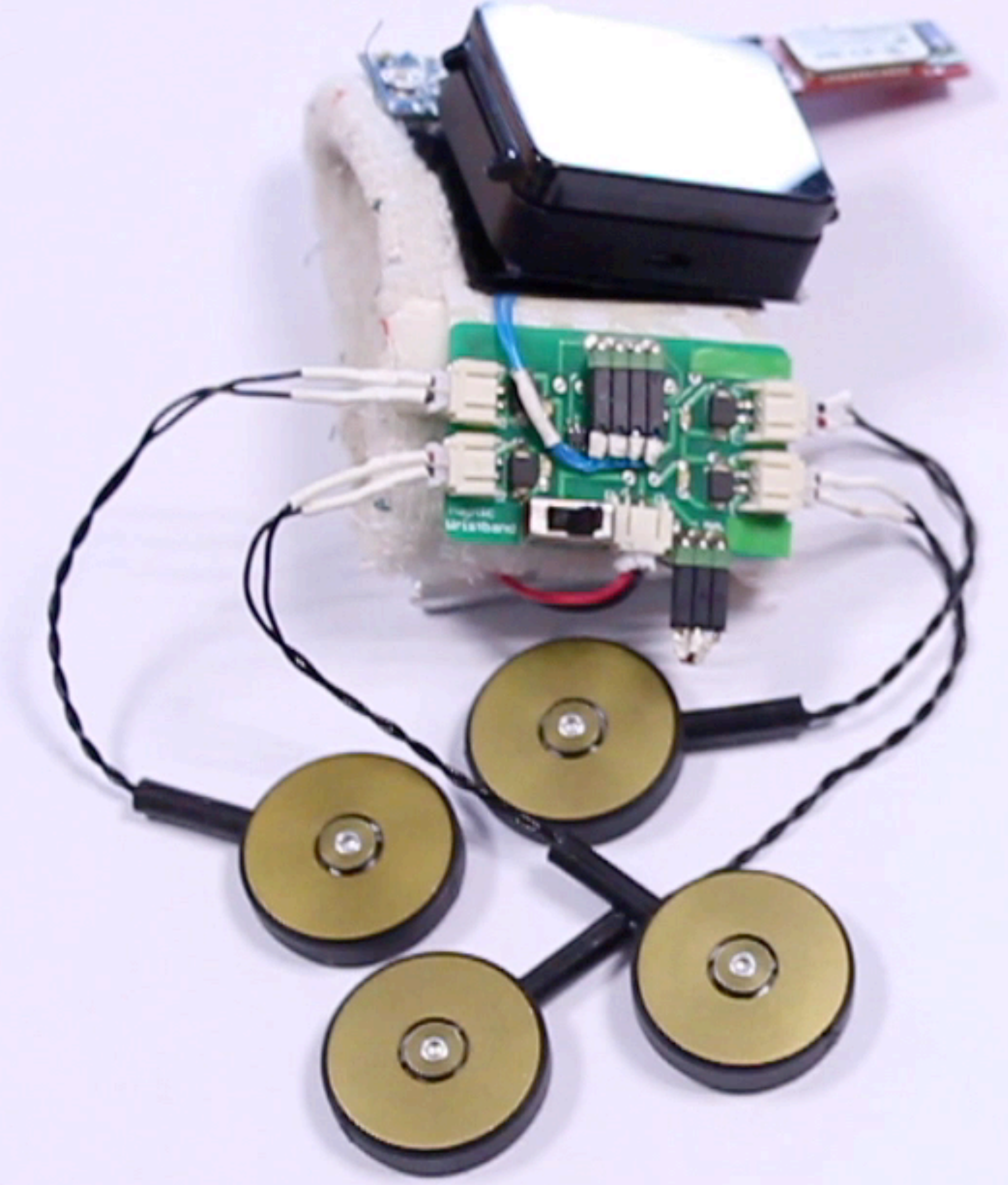


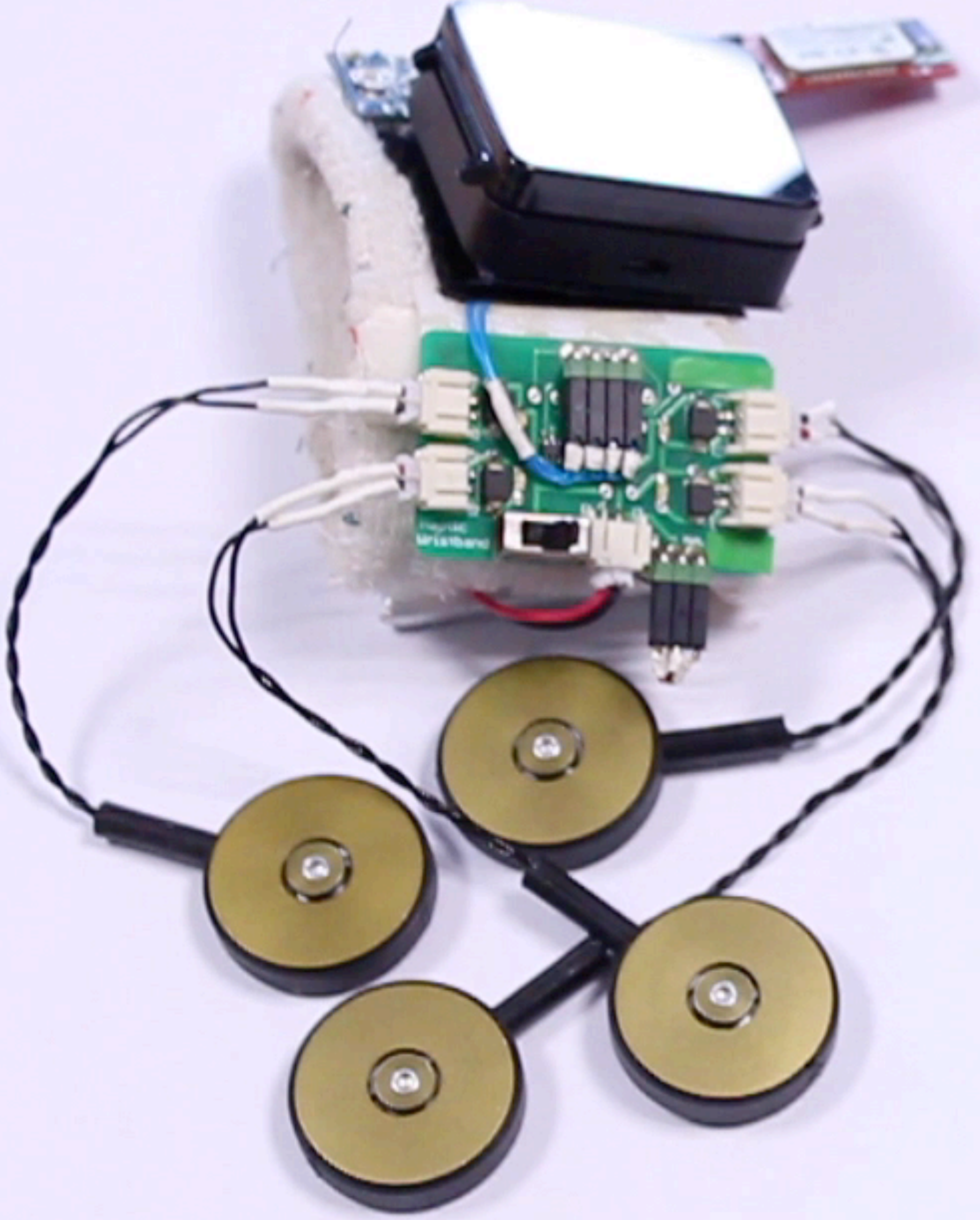
Métamorphe (Univ. Lille, UofT, 2013)



Métamorphe (Univ. Lille, UofT, 2013)



Direct Manipulation (Univ. Lille, UofT, Inria, 2016)



Direct Manipulation (Univ. Lille, UofT, Inria, 2016)

Living Desktop

(Télécom ParisTech, Inria, Univ. Lille, 2016)

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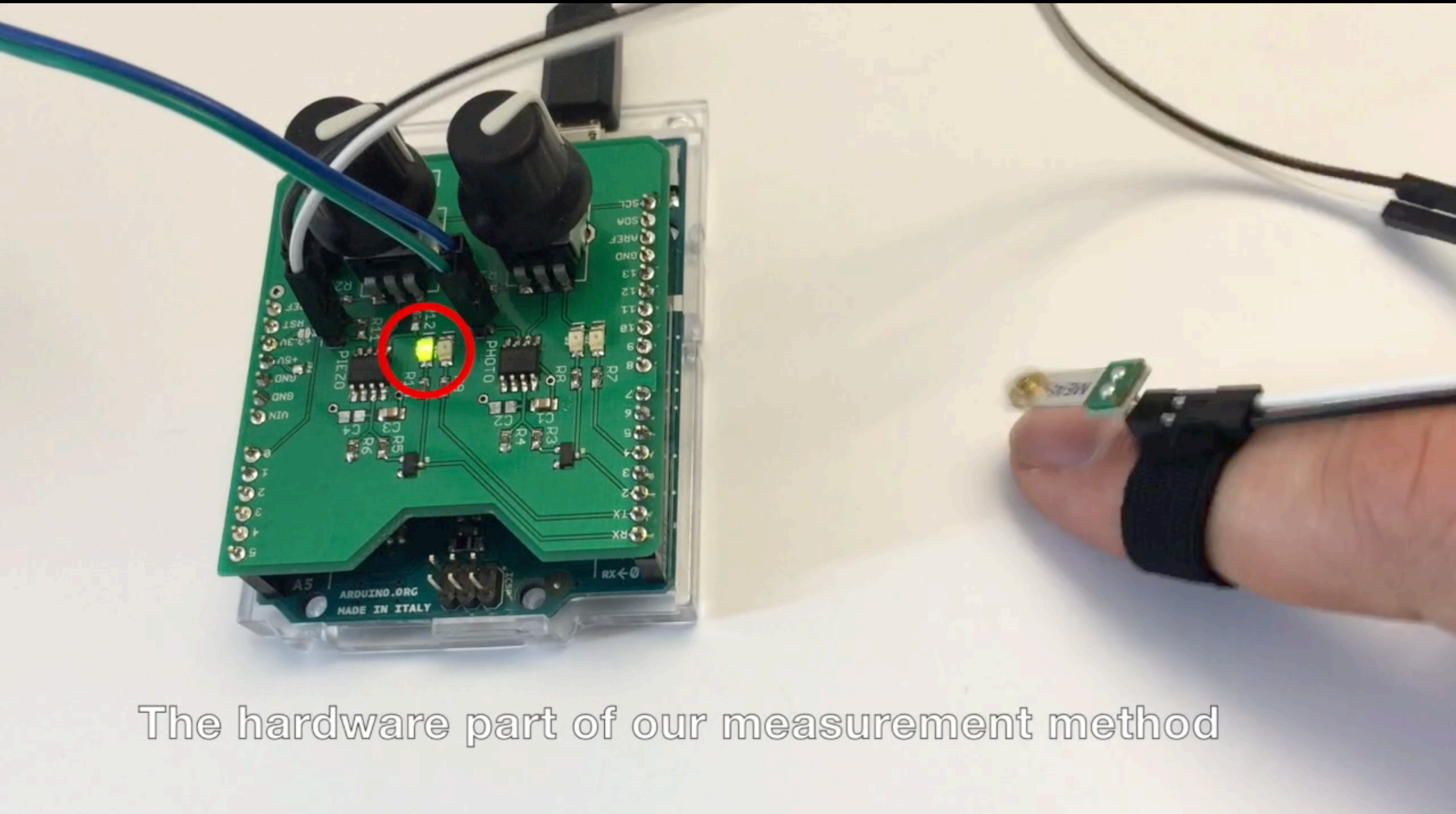
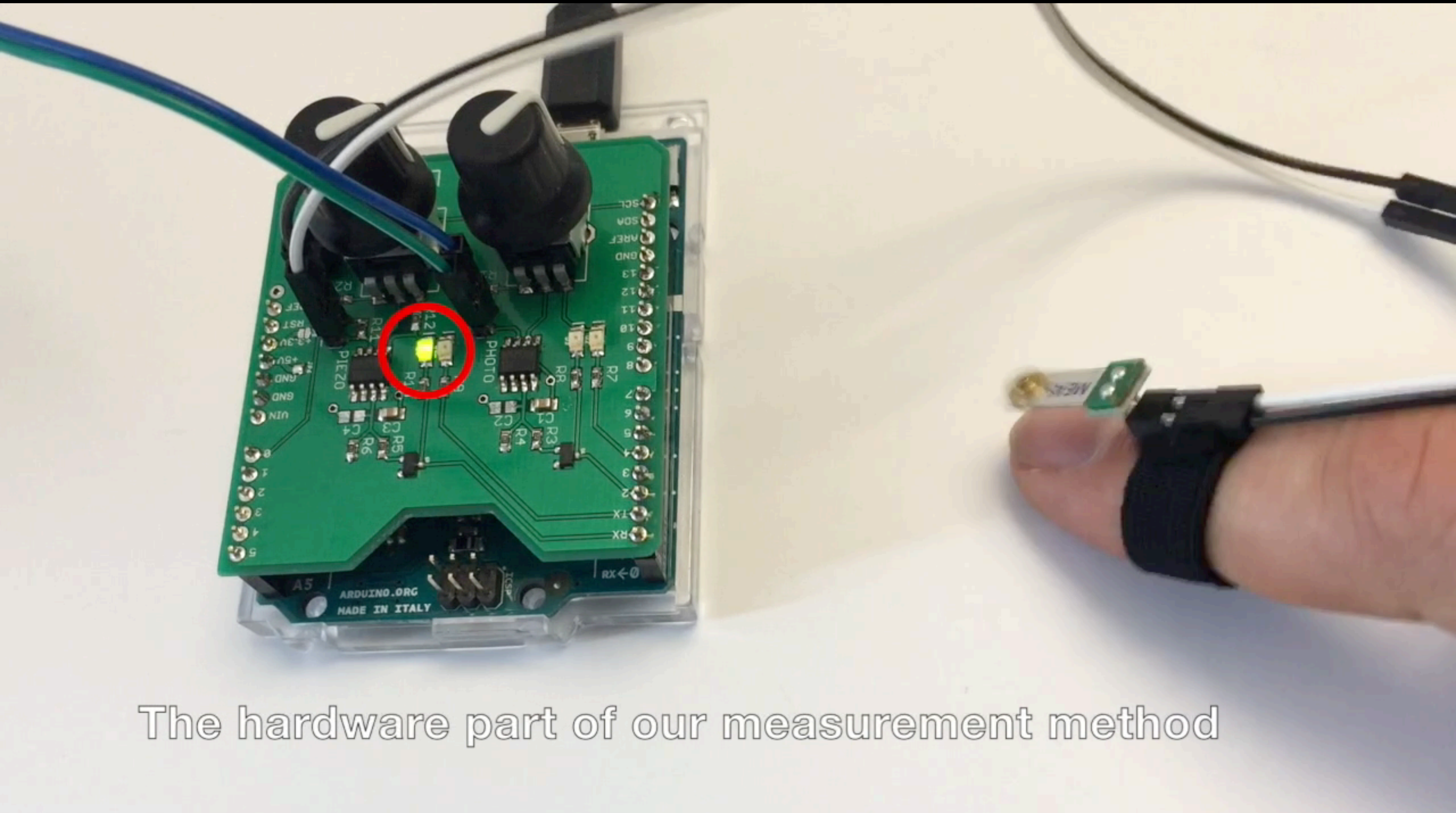
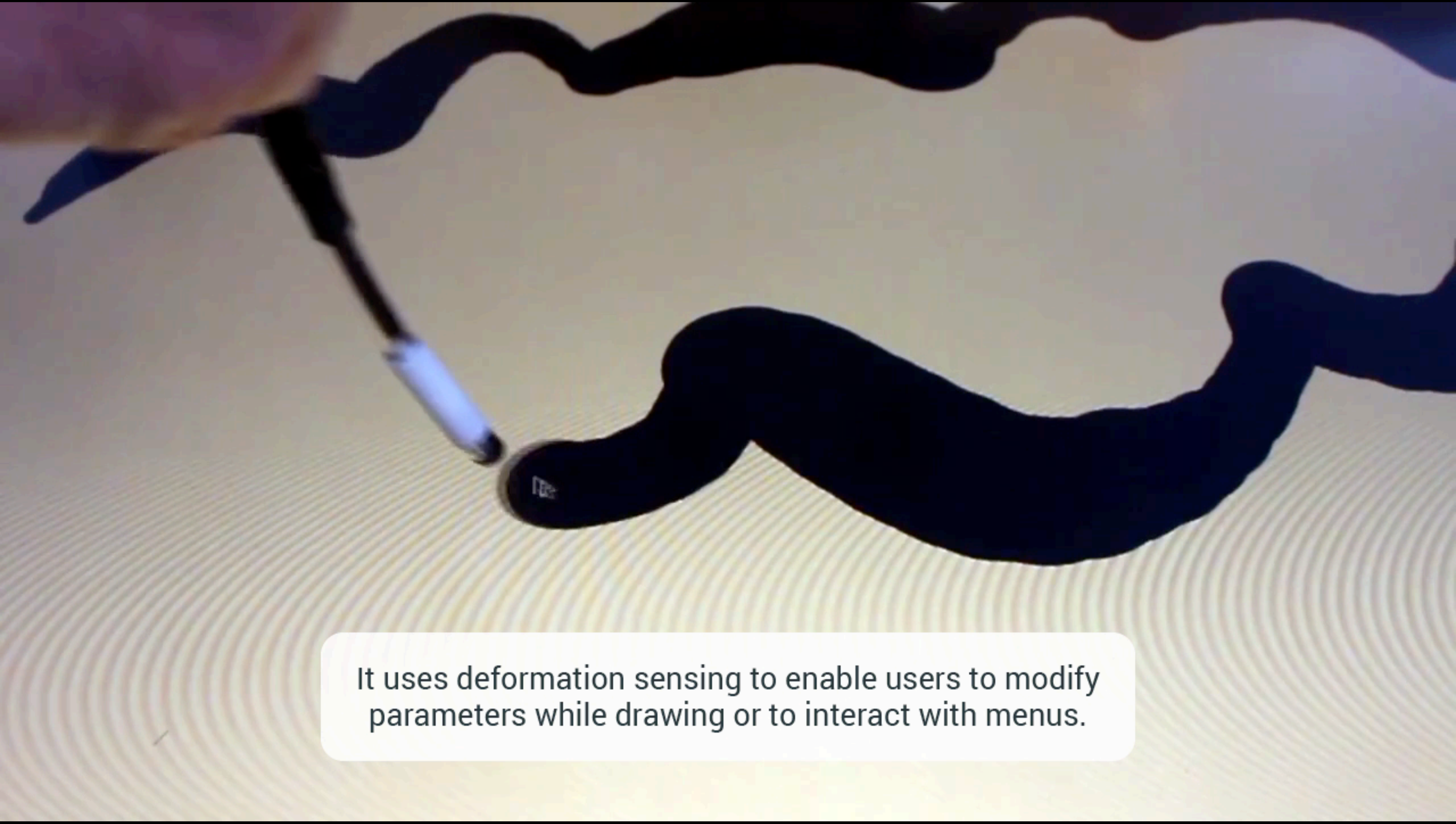


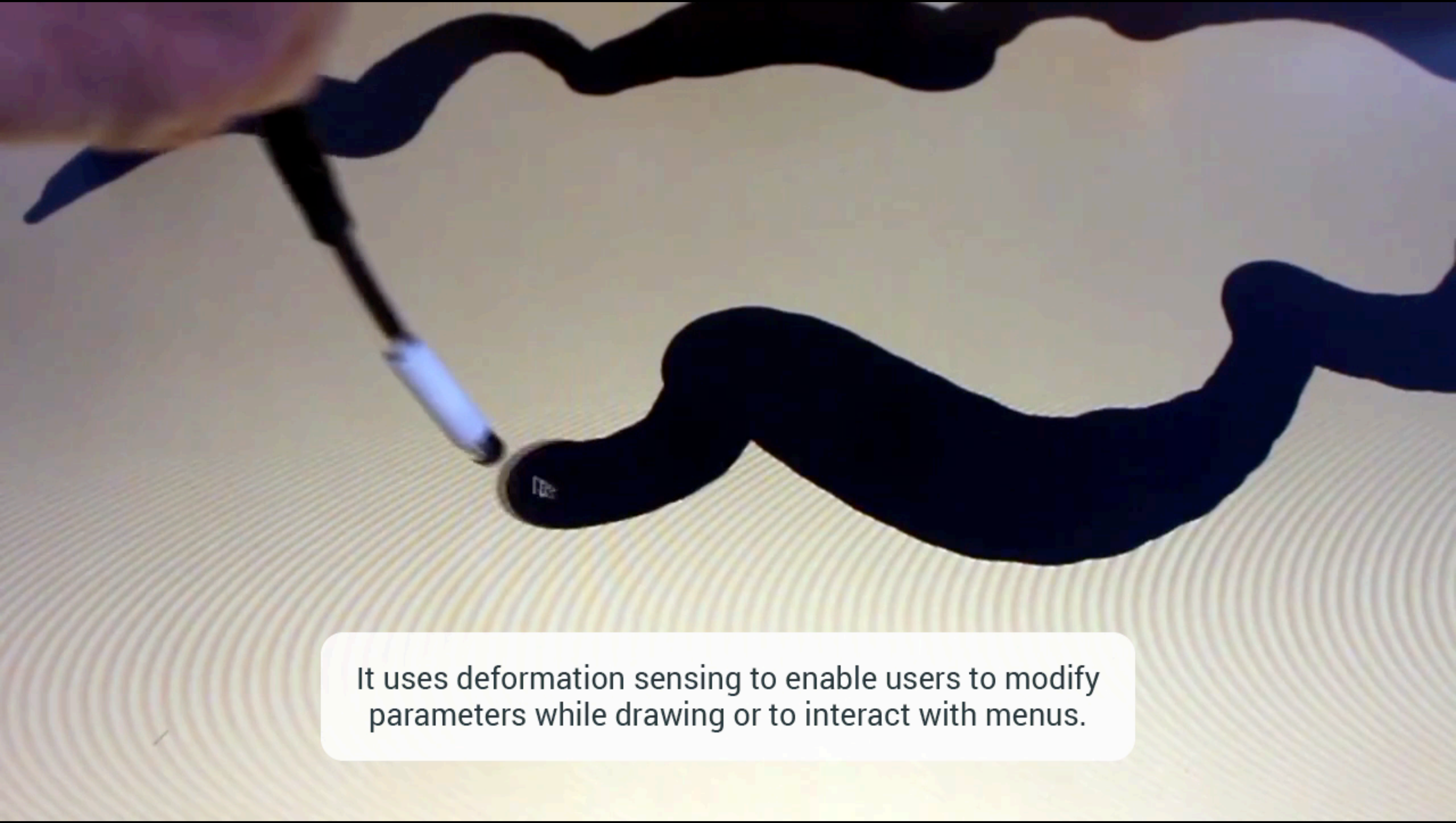
Lagmeter (Univ. Lille, Inria, 2017)



Lagmeter (Univ. Lille, Inria, 2017)



Flexstylus (Univ. Lille, UofT, Inria, 2017)



Flexstylus (Univ. Lille, UofT, Inria, 2017)

Rappels sur l'électricité

Les charges

- Électron : charge négative -
- Protons : charge positive +
- Même type se repoussent
- Type différent s'attirent
- Se déplacent facilement dans les conducteurs
- Se déplacent difficilement dans les isolants

Tension

- Unité : Volt (V)
- Accumulation d’électrons

Courant

- Unité : Ampère (A)
- Flux d’électrons

Puissance

- Unité : Watt (W)
- $P = UI$
- Plus on a de charges, plus on a de puissance
- Plus les chargent bougent plus on a de puissance

AC/DC

- AC : Alternating Current ⇒ courant alternatif
  - Le courant change de direction périodiquement
  - Facile à créer, mécaniquement par exemple
  - Prise de courant, etc.
- DC : Direct Current ⇒ courant continu
  - Le courant circule dans une seule direction
  - Le courant doit revenir à la source
  - Pile, batterie, etc.

R L C

Résistance

Résistance

- Unité : Ohm (Ω)
- Code couleurs

0	1	2	3	4	5	6	7	8	9

- Résistance interne : impédance
- Loi d'OHM : $U = RI \Rightarrow I = U/R$
  - Une grande résistance diminue le flux
  - Une petite résistance ne s'oppose pas au flux.

Circuit série

$R_t = R_1 + R_2 + R_3$

$I_t = I_1 = I_2 = I_3$

$U_1 = R_1 I_1$

$U_2 = R_2 I_2$

$U_3 = R_3 I_3$

$\Rightarrow U_t = U_1 + U_2 + U_3$

Circuit parallèle

$1/R_t = 1/R_1 + 1/R_2 + 1/R_3$

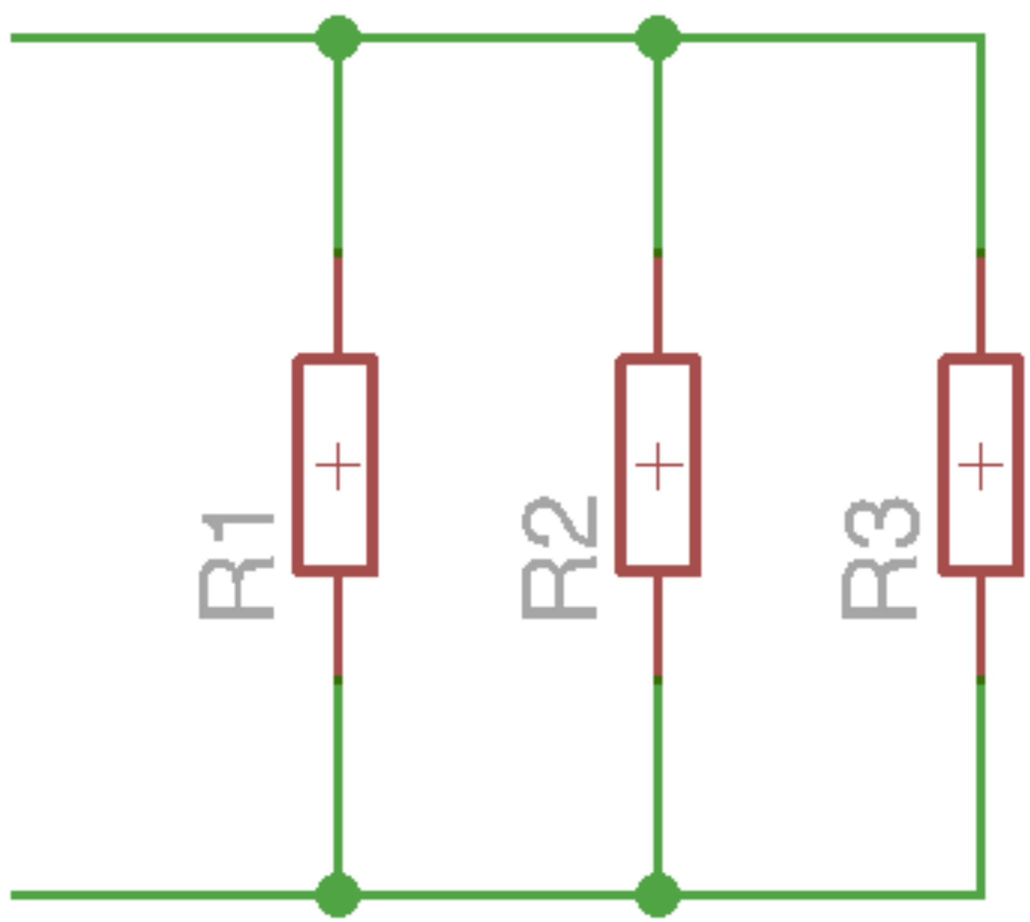
$U_t = U_1 = U_2 = U_3$

$I_1 = U_1/R_1$

$I_2 = U_2/R_2$

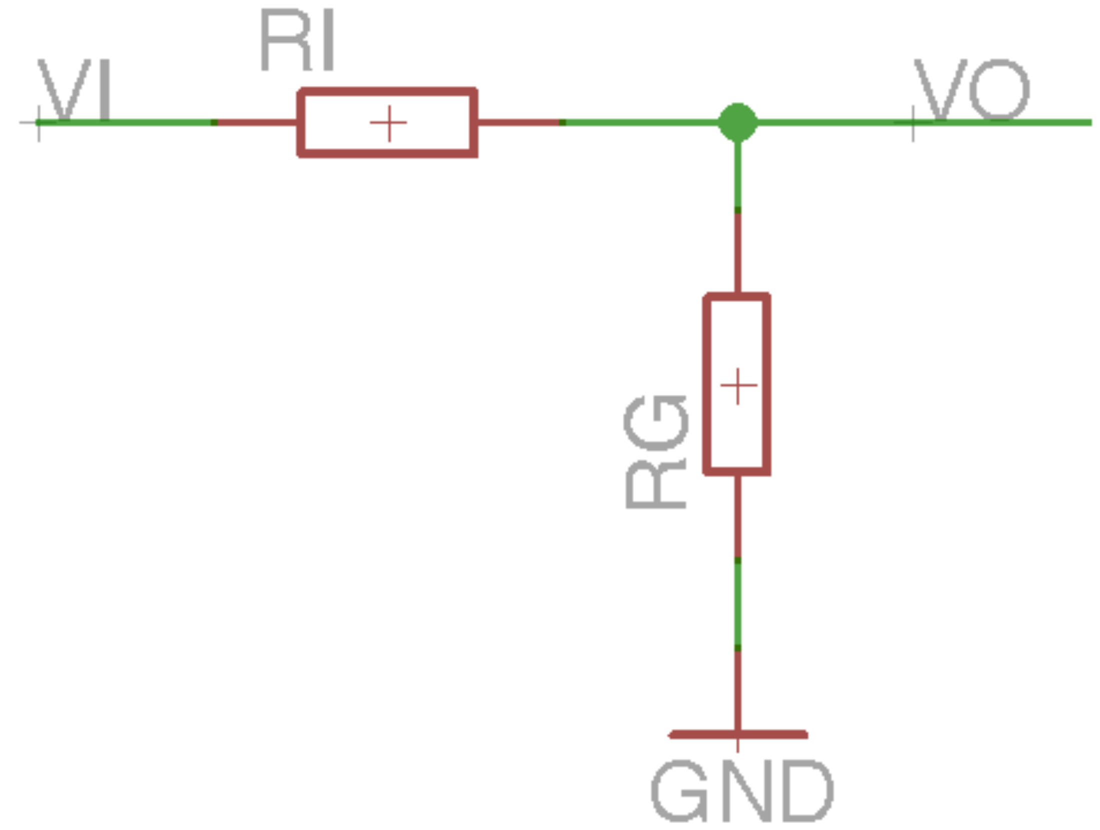
$I_3 = U_3/R_3$

$\Rightarrow I_t = I_1 + I_2 + I_3$



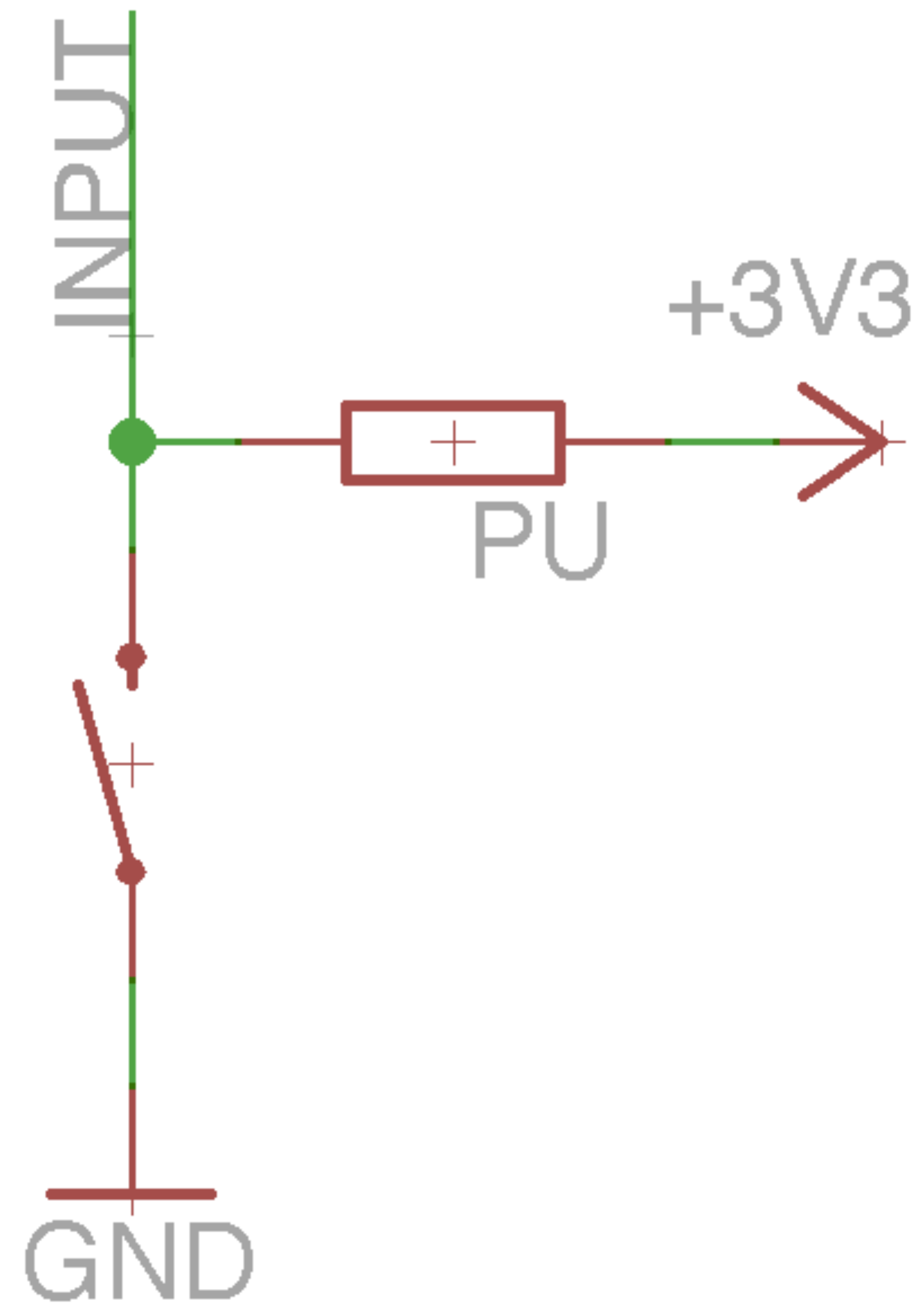
Diviseur de tension

$$V_o = V_i \frac{R_g}{R_g + R_i}$$



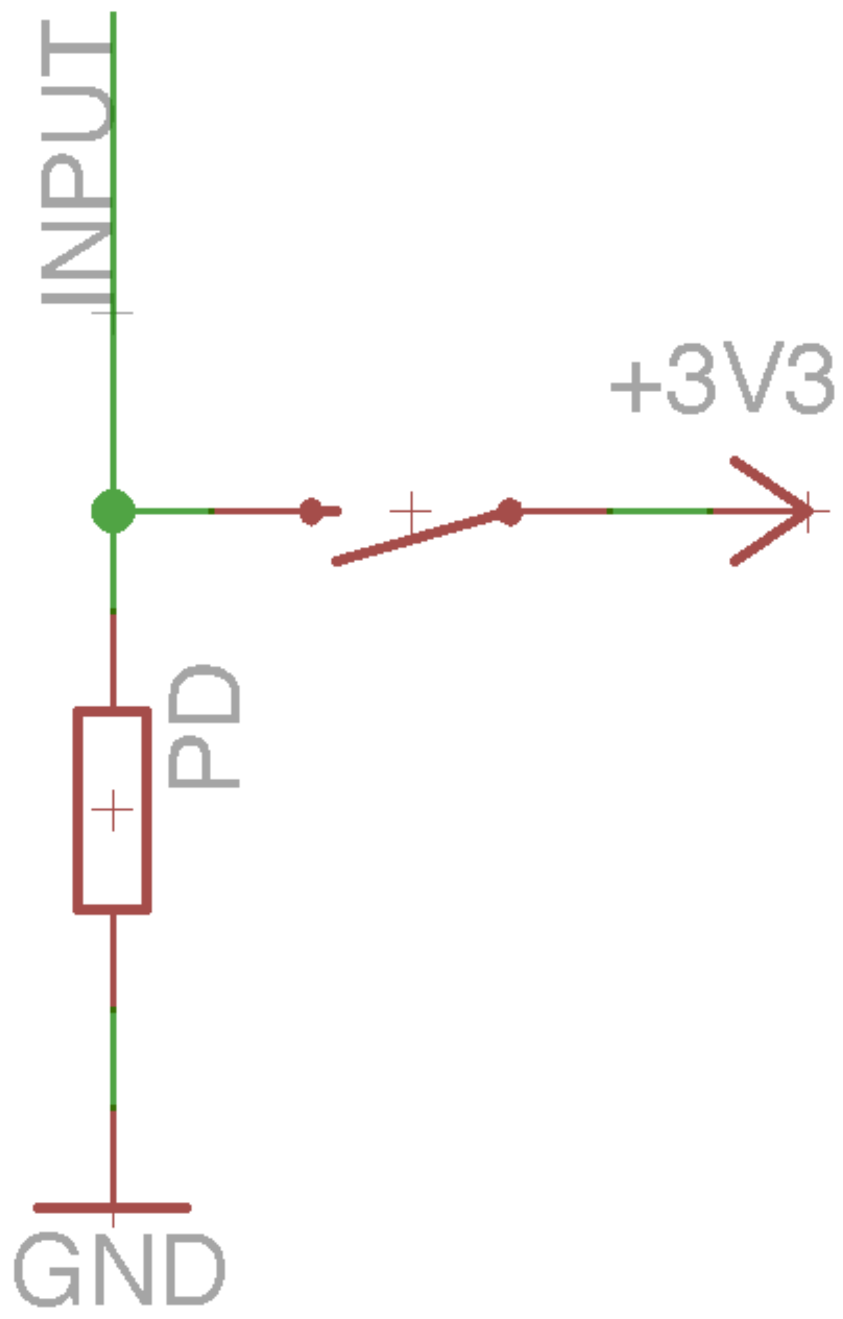
Pull-up

INPUT = HIGH par défaut



Pull-down

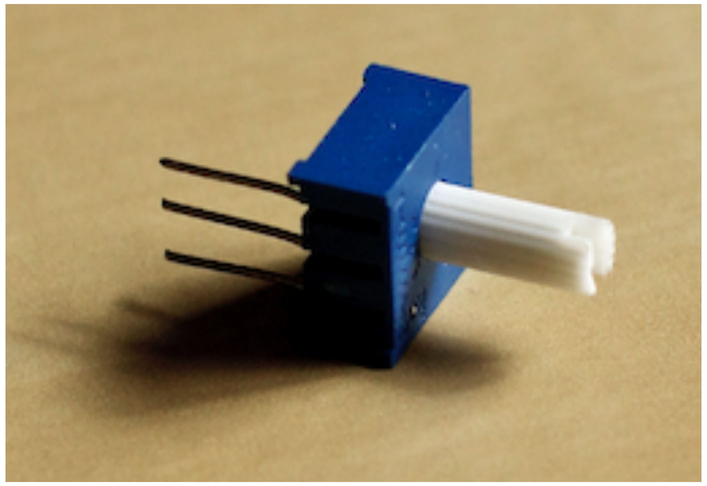
INPUT = LOW par défaut

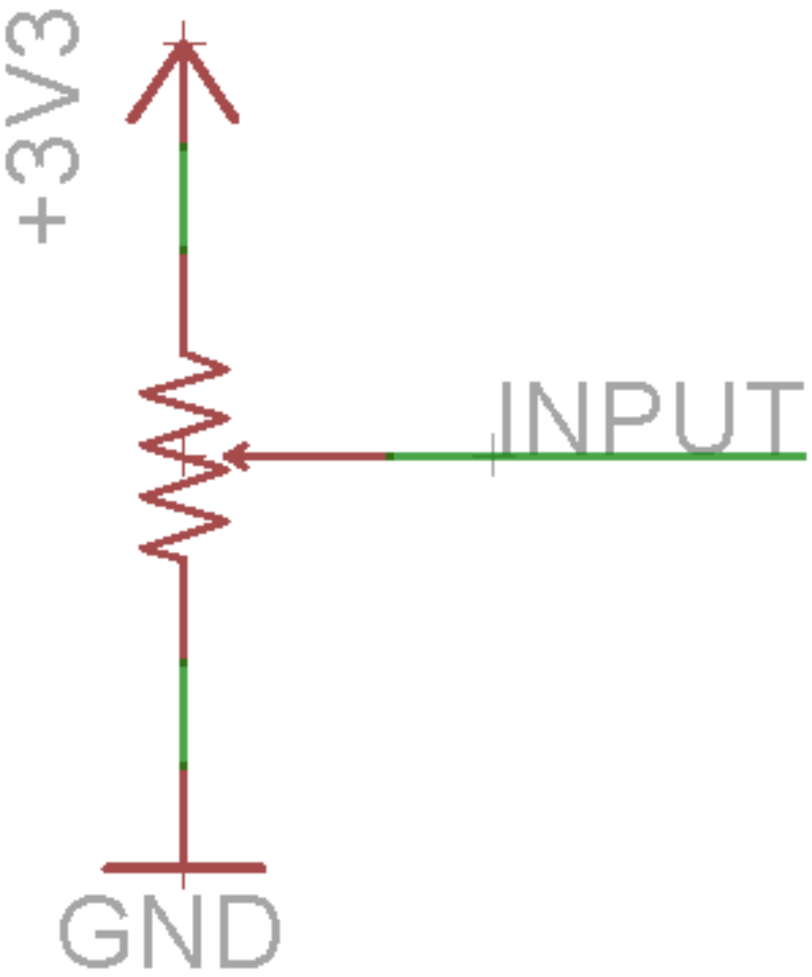


Potentiomètre

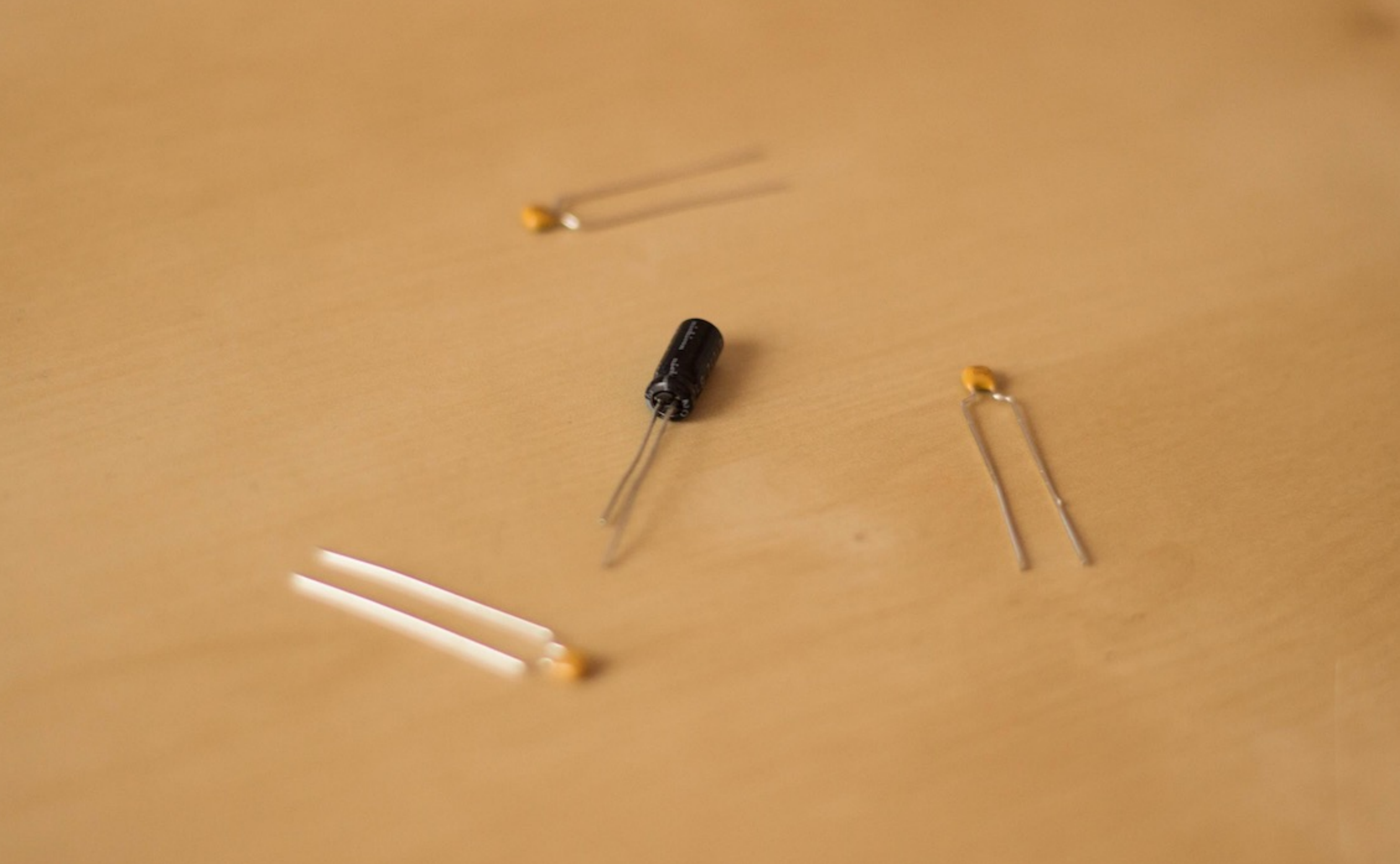
Résistance variable

Bouton pour ajuster la valeur

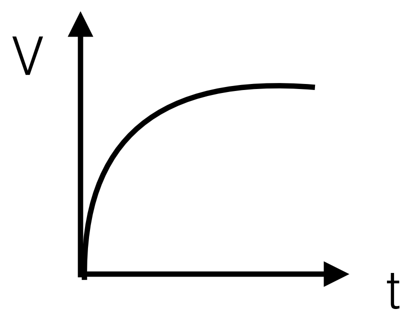




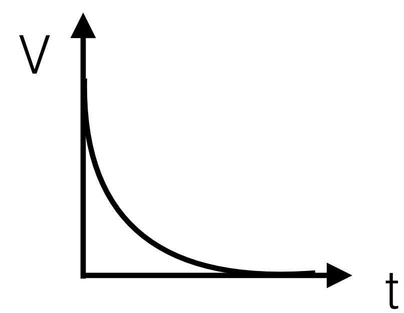
Codensateur



Condensateur



Charge



Décharge

$$capacitance = \frac{courant \times temps}{tension}$$

$$\frac{tension}{intensite} = \frac{temps}{capacitance}$$

$$impedence = \frac{temps}{capacitance}$$

$$impedance = \frac{1}{frequence \times capacitance}$$

équations simplifiées

- Impédance dépend de la fréquence du signal
  - Haute fréquences (ex : changements brusques) : basse impédance
  - Basse fréquence (ex : signal constant) : haute impédance

Circuits série

$I_t = I_1 = I_2 = I_3$

$U_t = U_1 + U_2 + U_3$

$$C = \frac{I \times t}{U}$$

$1/C_t = 1/C_1 + 1/C_2 + 1/C_3$

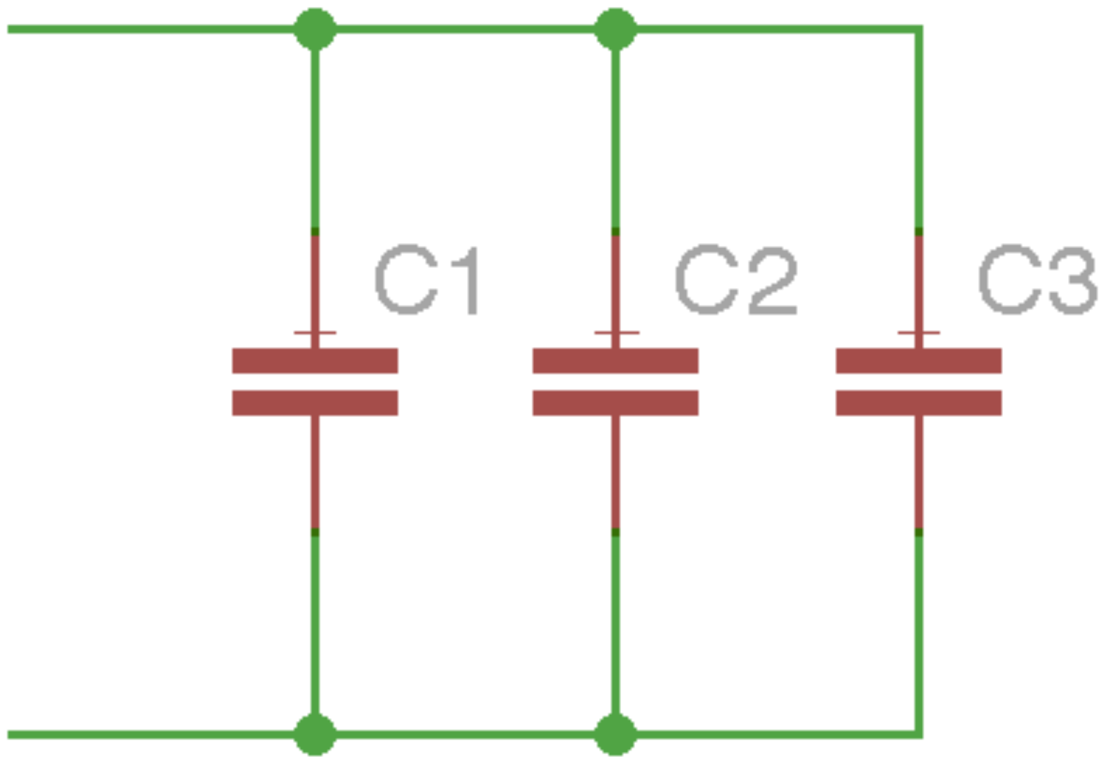
Circuits parallèle

$U_t = U_1 = U_2 = U_3$

$I_t = I_1 + I_2 + I_3$

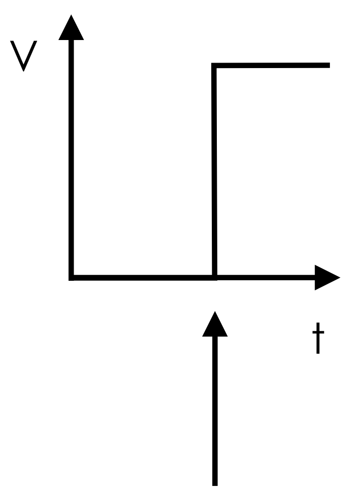
$$C = \frac{I \times t}{U}$$

$C_t = C_1 + C_2 + C_3$



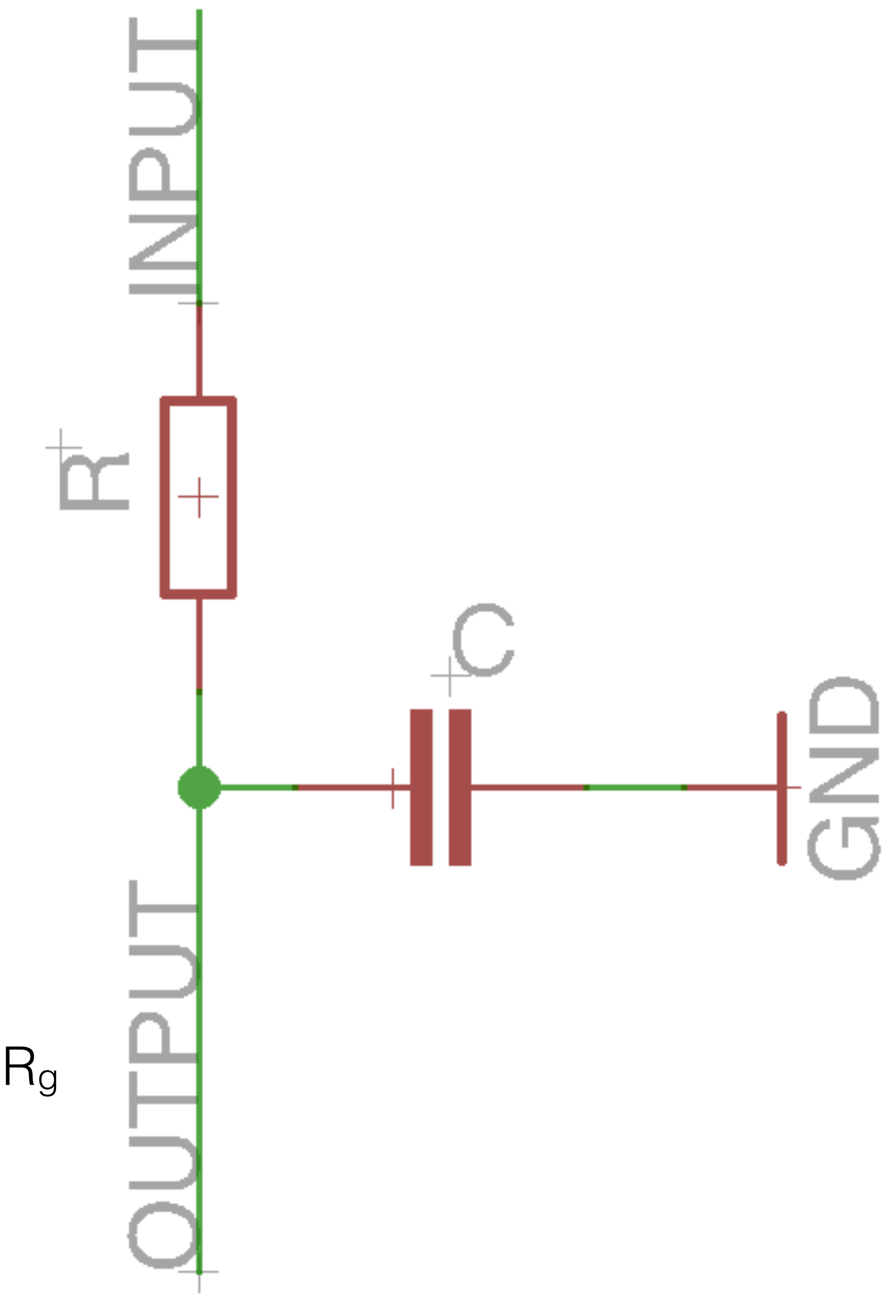
Filtre passe bas (RC)

Éviter de brusquer l'output



Haute fréquence
⇒ basse impédance

Diviseur de tension
Avec C à la place de R_g

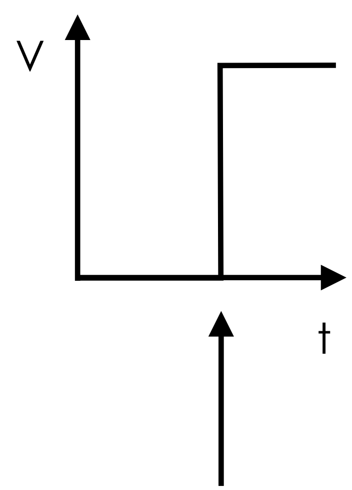


$$V_o = V_i \frac{Z}{Z + R}$$

$$Z = \frac{1}{fC}$$

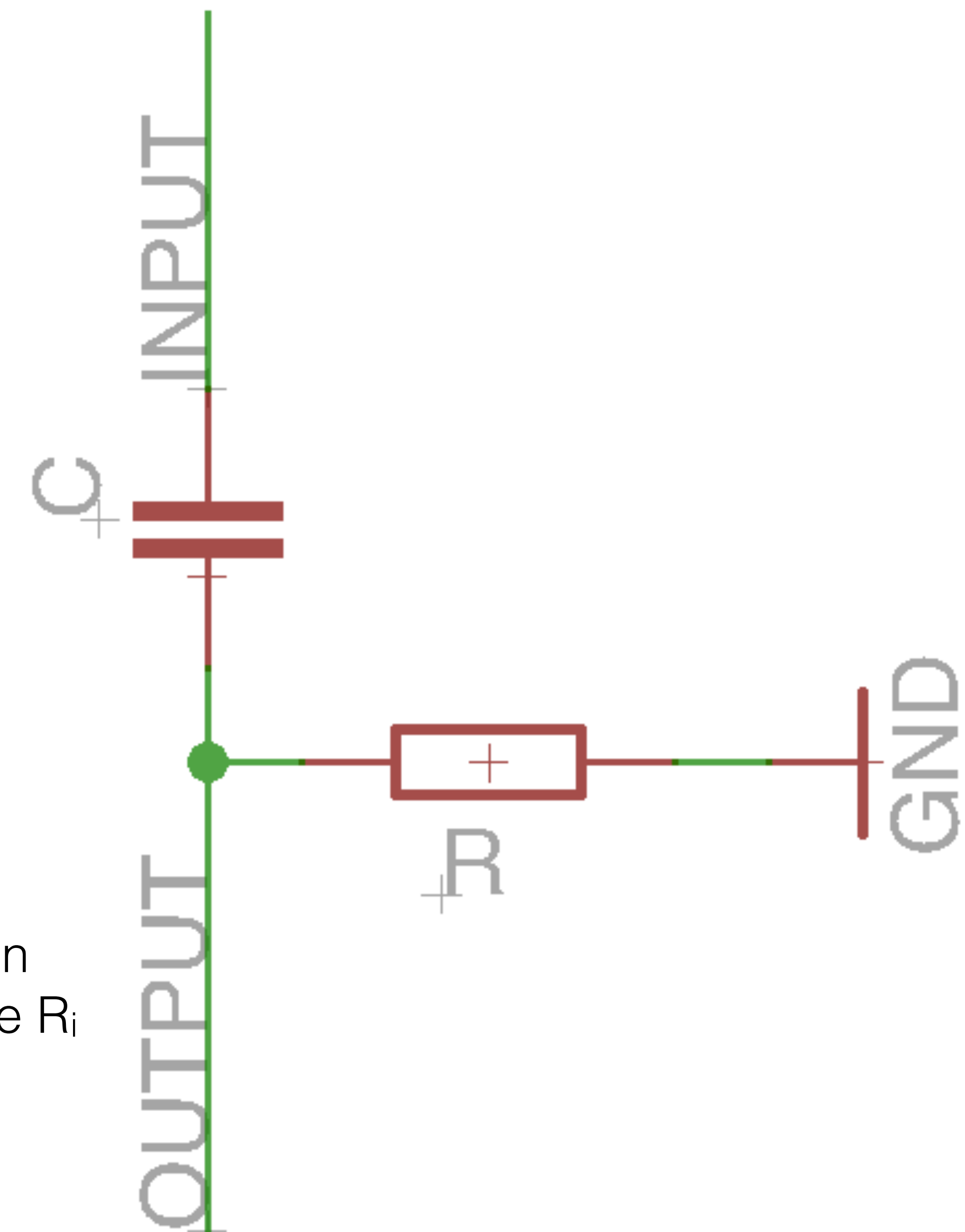
$$V_o = V_i \frac{1}{fC\left(\frac{1}{fC} + R\right)}$$

Filtre passe haut (RC)



Haute fréquence
⇒ basse impédance

Diviseur de tension
Avec C à la place de R_i

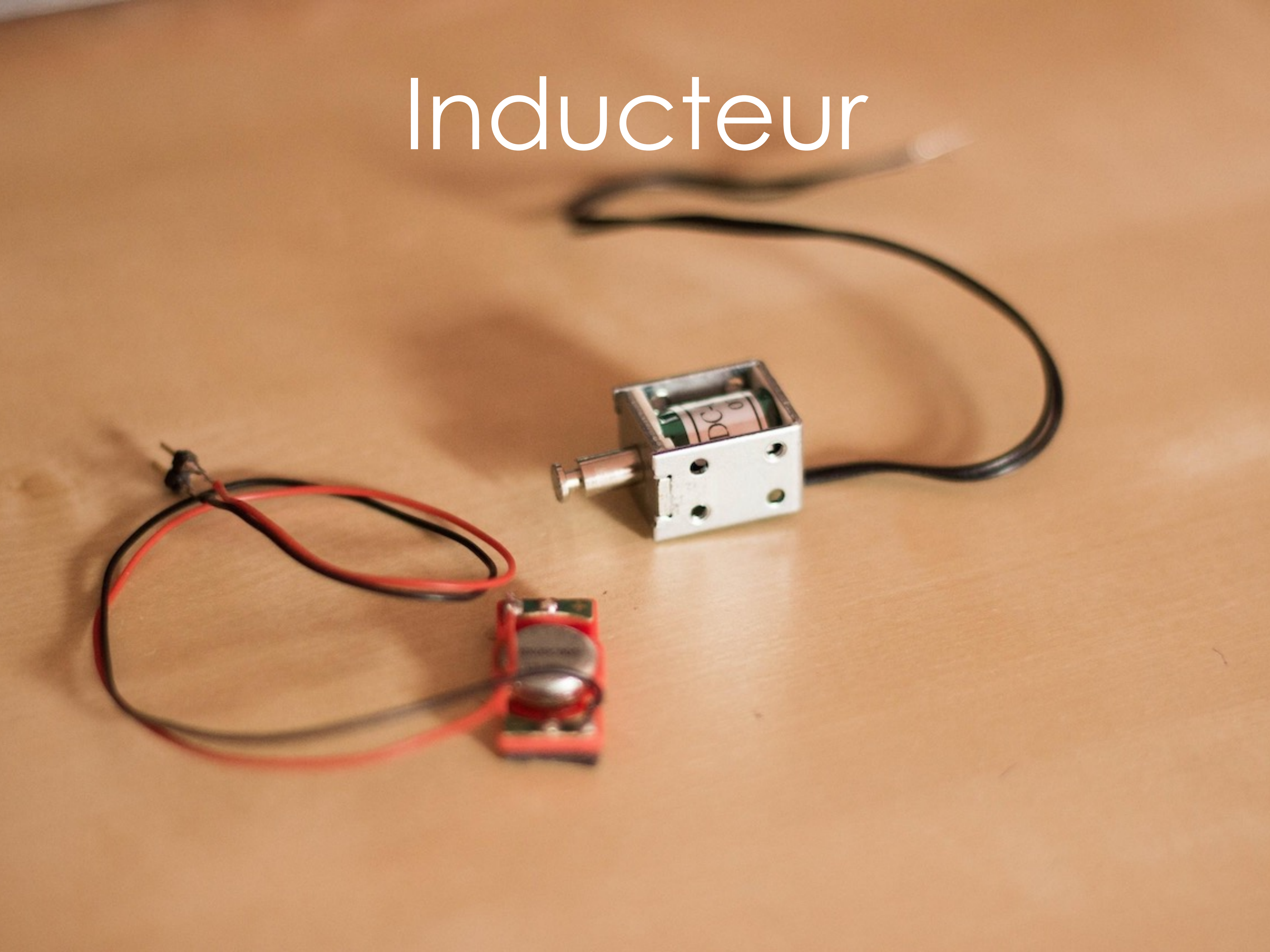


$$V_o = V_i \frac{R}{R + Z}$$

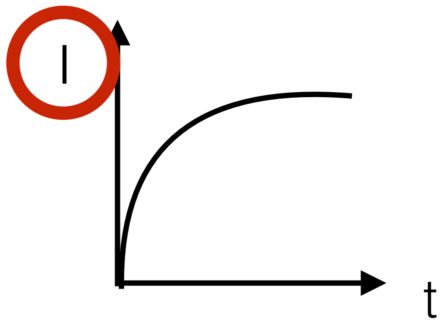
$$Z = \frac{1}{fC}$$

$$V_o = V_i \frac{R}{R + \frac{1}{fC}}$$

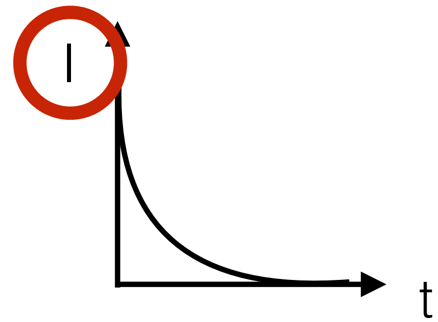
Inducteur



Inducteur



Charge



Décharge

$$inductance = \frac{tension \times temps}{intensite}$$

$$inductance = impedence \times temps$$

$$impedence = \frac{inductance}{temps}$$

$$impedence = frequence \times inductance$$

- Impédance dépend de la fréquence du signal
  - Haute fréquences (ex : changements brusques) : haute impédance
  - Basse fréquence (ex : signal constant) : basse impédance

Circuits série

$I_t = I_1 = I_2 = I_3$

$U_t = U_1 + U_2 + U_3$

$$L = \frac{U \times t}{I}$$

$L_t = L_1 + L_2 + L_3$

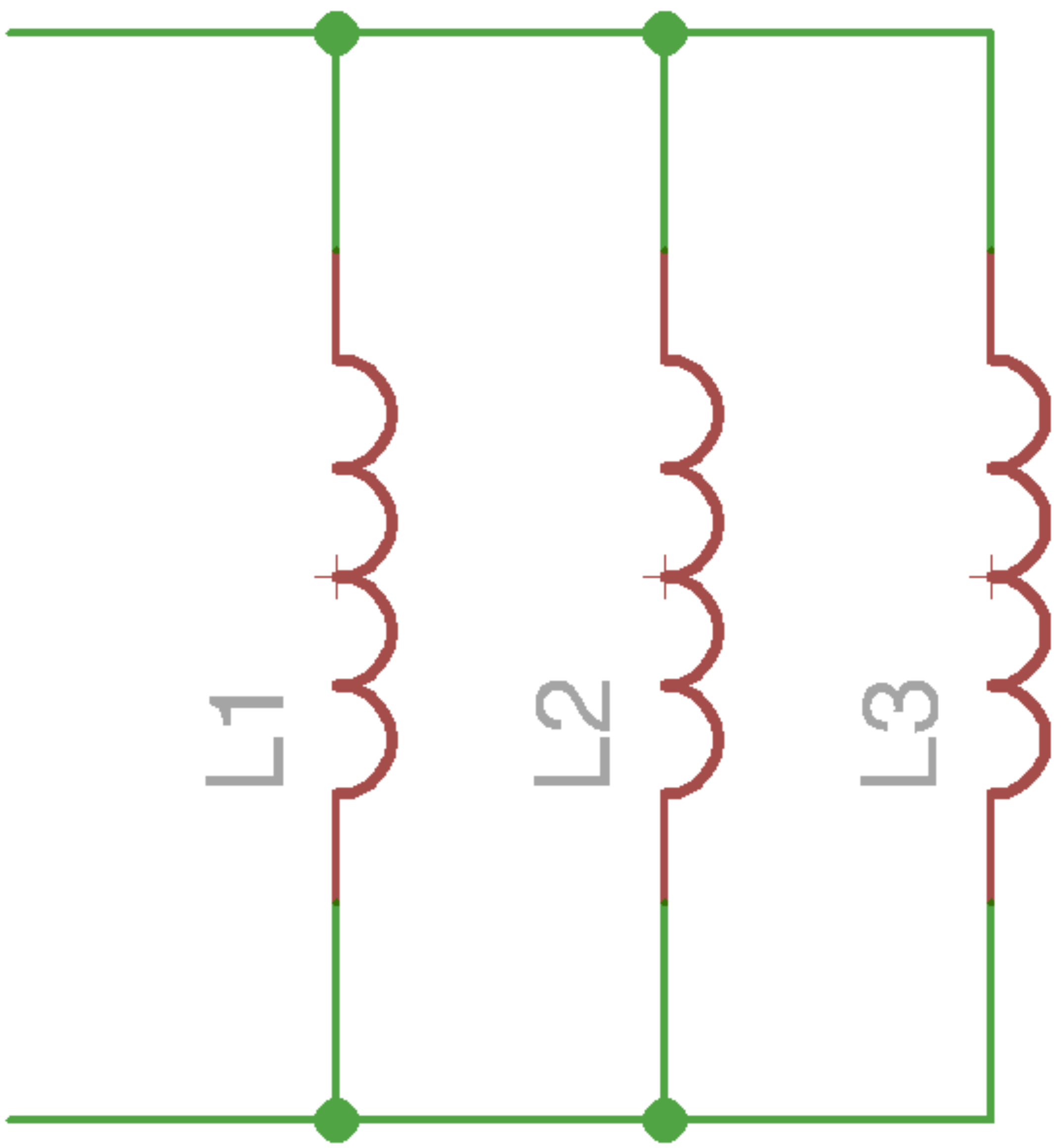
Circuits parallèle

$U_t = U_1 = U_2 = U_3$

$I_t = I_1 + I_2 + I_3$

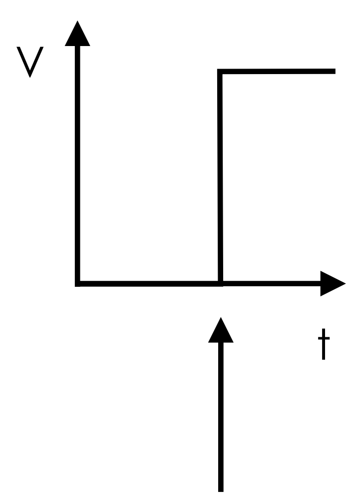
$$L = \frac{U \times t}{I}$$

$1/L_t = 1/L_1 + 1/L_2 + 1/L_3$



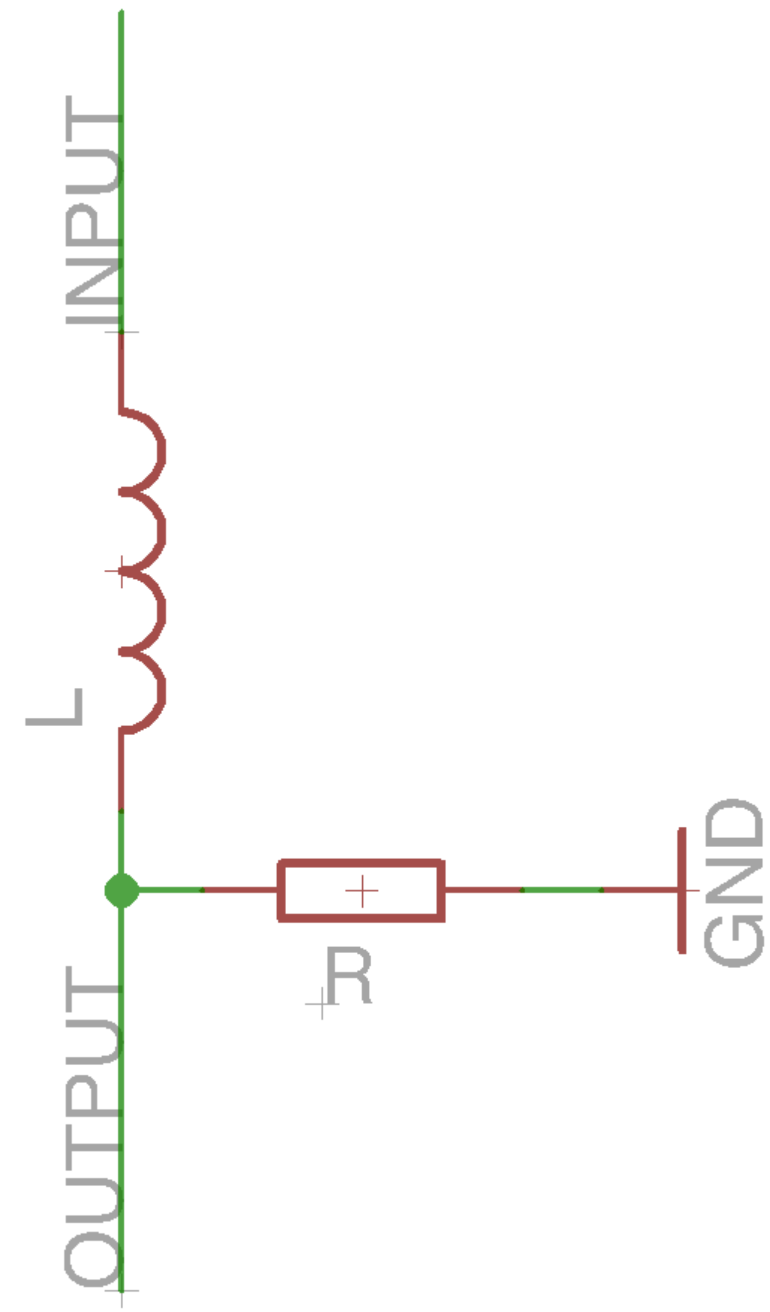
Filtre passe bas (RL)

Éviter de brusquer l'output



Haute fréquence
⇒ haute impédance

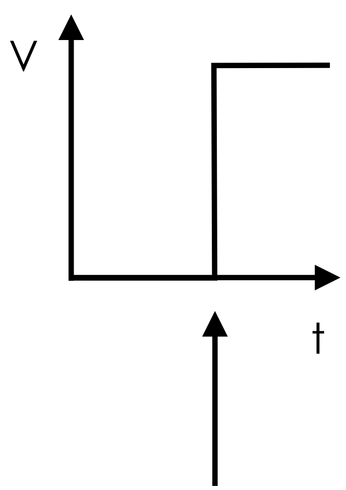
Diviseur de tension
Avec L à la place de R_i



$$V_o = V_i \frac{R}{R + Z} \qquad Z = fL \qquad V_o = V_i \frac{R}{R + fL}$$

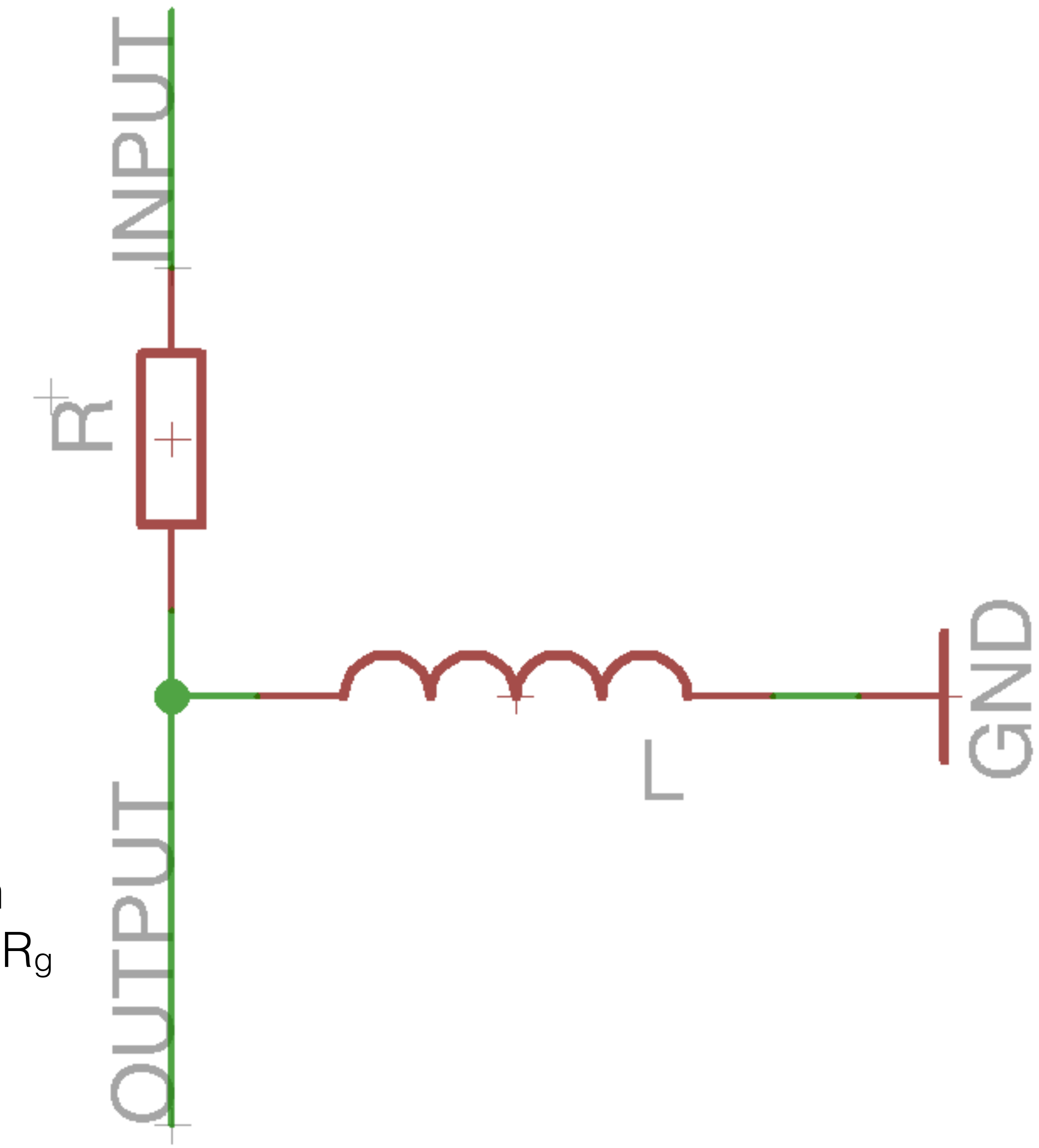
Filtre passe haut (RL)

Éviter de brusquer l'output



Haute fréquence
⇒ haute impédance

Diviseur de tension
Avec L à la place de R_g



$$V_o = V_i \frac{Z}{Z + R}$$

$$Z = fL$$

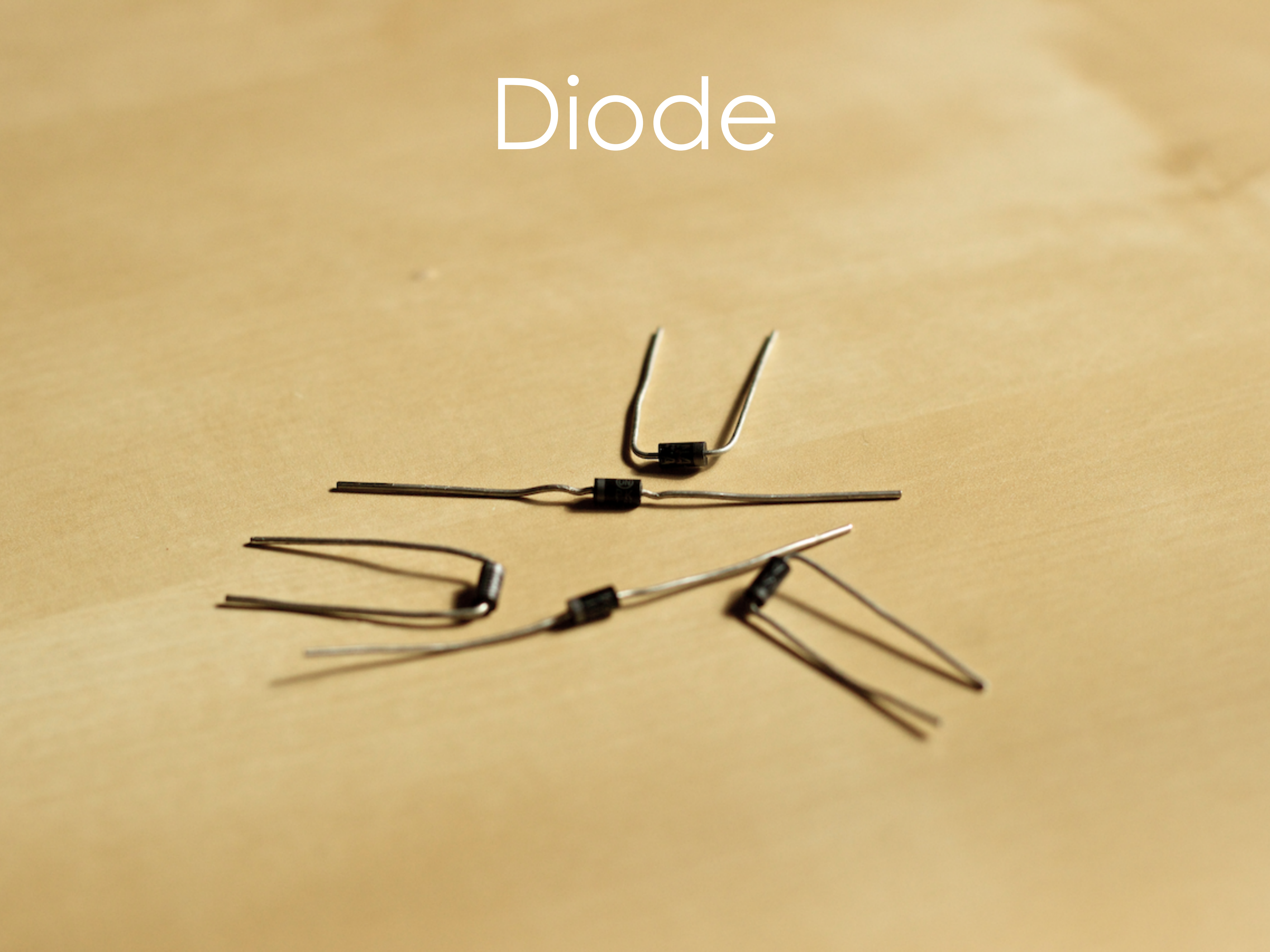
$$V_o = V_i \frac{fL}{fL + R}$$

Semi-conducteurs

Semi-conducteurs

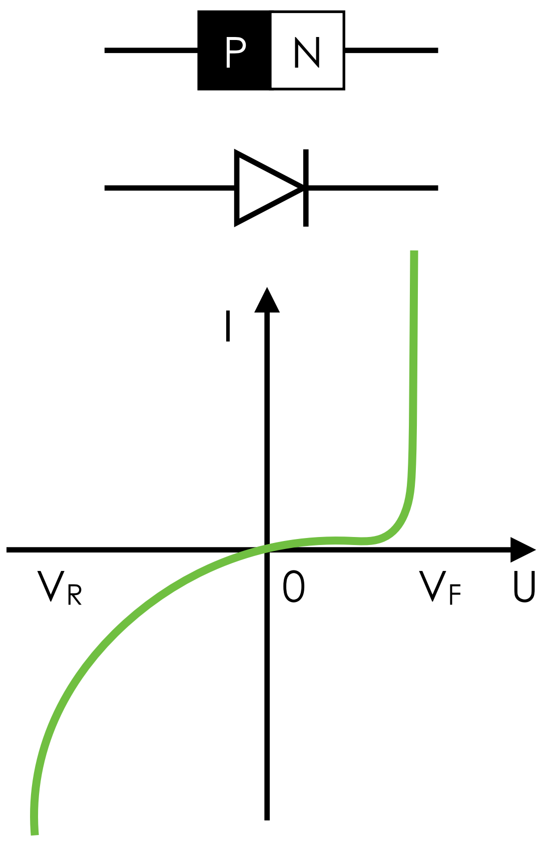
- À mi-chemin entre conducteur et isolant
- Quantité d'électrons modifiés par **dopage**
- Type N : excès d'électrons
- Type P : défaut d'électrons

Diode



Diode

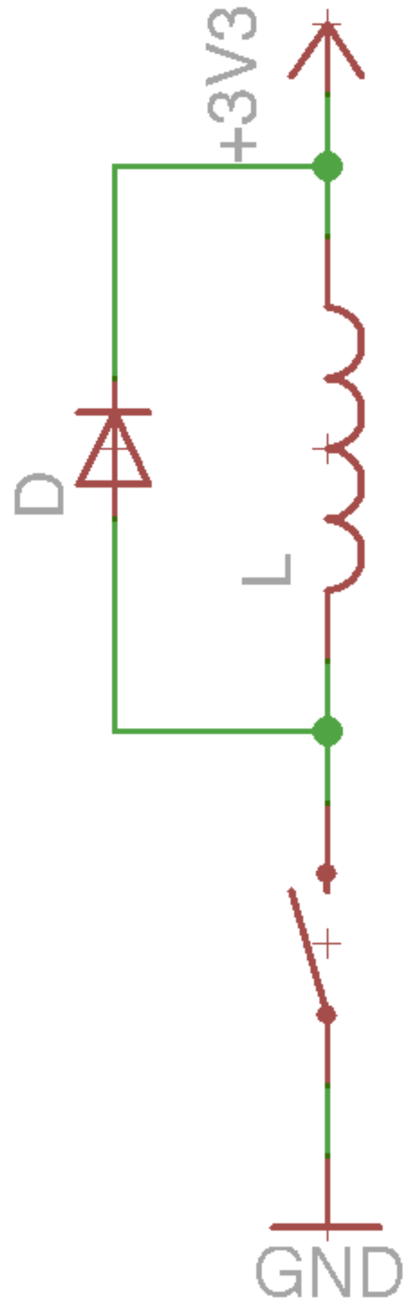
- Assemblage de deux semi-conducteurs
- Cathode : jonction N (excès d'électrons)
- Anode : jonction P (défaut d'électrons)
- Sens passant (P+/N-)
- Sens bloquant (N+/P-)
- Tension seuil V_F (Forward voltage)
- Tension au bornes V_R quand bloquée (Reverse voltage)



Diode de flyback

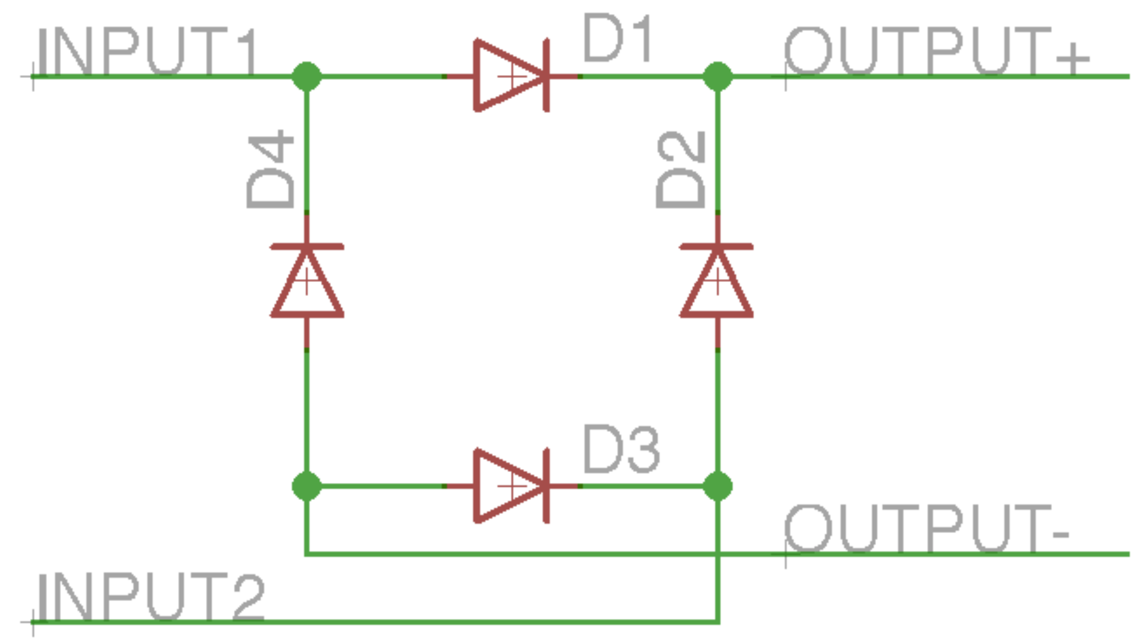
Éviter le courant induit lors des changements brusques

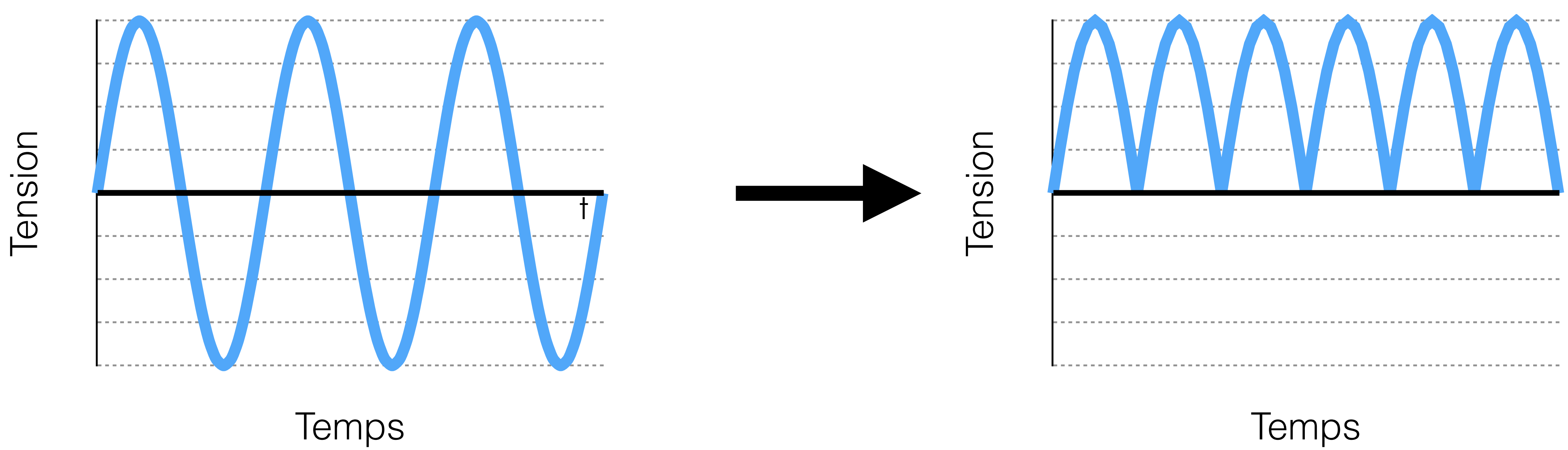
Utile sur des moteurs, vibreurs, etc.



Pont de diodes

Transformer AC en DC

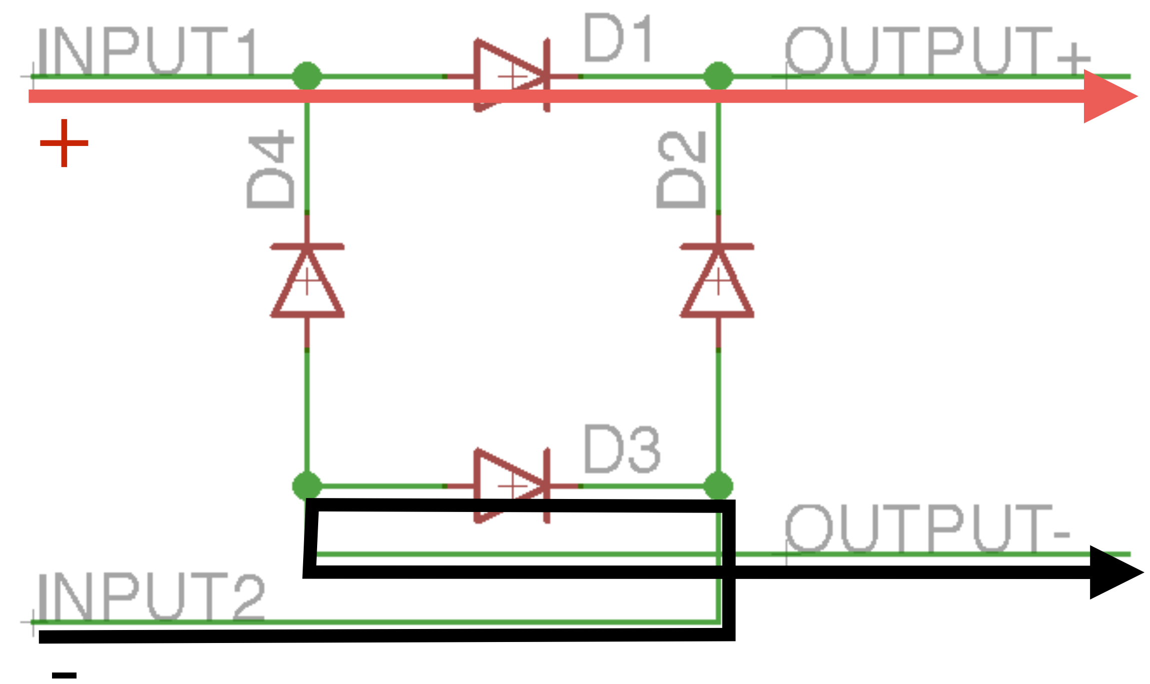


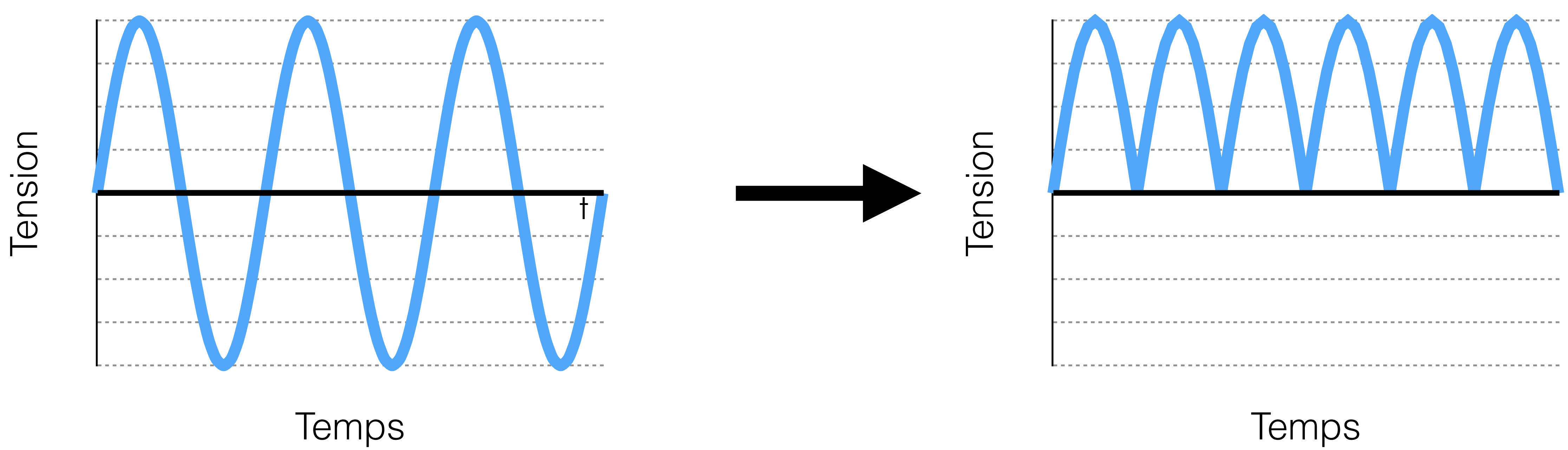


Pont de diodes

Transformer AC en DC

$I_1 + \Rightarrow D_1 \Rightarrow O_+$ $I_2 - \Rightarrow D_3 \Rightarrow O_-$

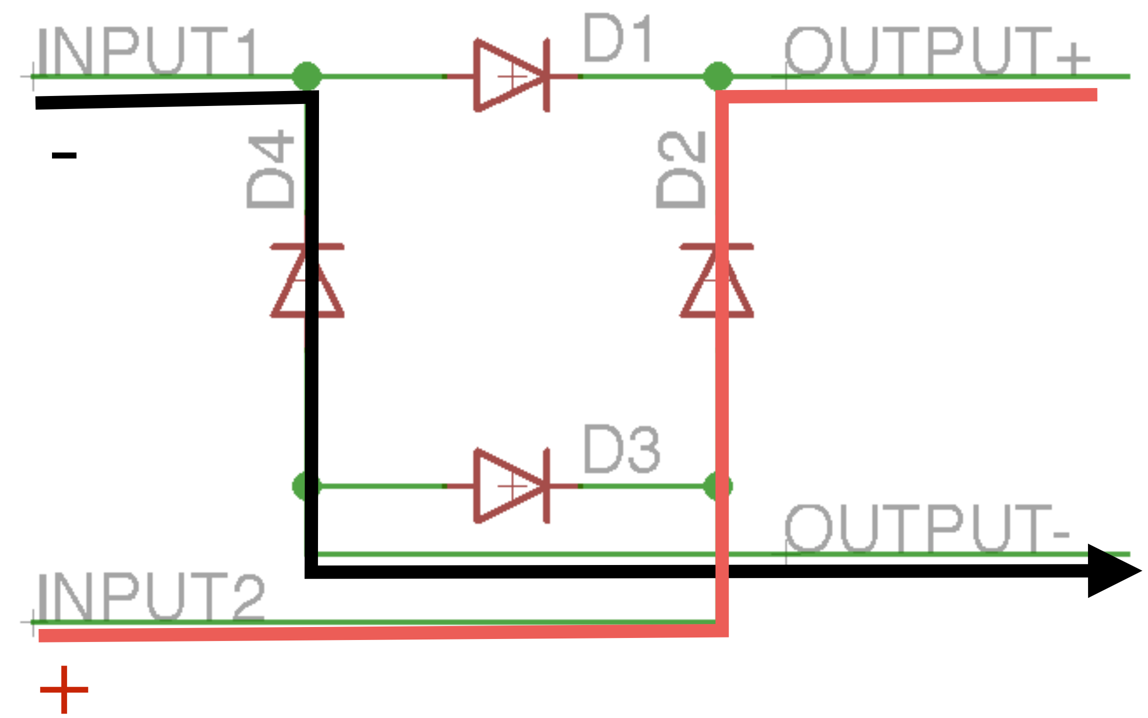


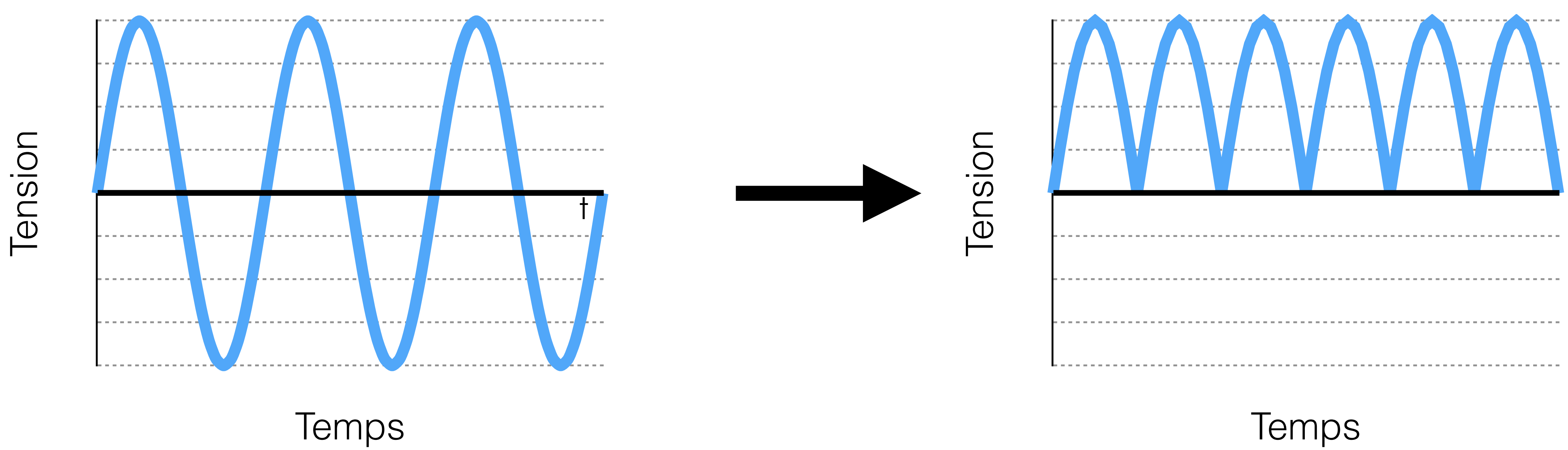


Pont de diodes

Transformer AC en DC

$I_1 - \Rightarrow D_4 \Rightarrow O_-$ $I_2 + \Rightarrow D_2 \Rightarrow O_+$





1N4001 thru 1N4007

Vishay General Semiconductor

General Purpose Plastic Rectifier

DO-204AL (DO-41)

	PRIMARY CHARACTERISTICS	
Forward current (continu)	$I_{F(AV)}$	1.0 A
Reverse voltage	V_{RRM}	50 V to 1000 V
Forward current (pic répété)	I_{FSM} (8.3 ms sine-wave)	30 A
Forward current (pic)	I_{FSM} (square wave t_p = 1 ms)	45 A
Forward voltage	V_F	1.1 V
Reverse current	I_R	5.0 µA
	T_J max.	150 °C

FEATURES

- Low forward voltage drop
- Low leakage current
- High forward surge capability
- Solder dip 275 °C max. 10 s, per JESD 22-B106
- Compliant to RoHS Directive 2002/95/EC and in accordance to WEEE 2002/96/EC

RoHS COMPLIANT

TYPICAL APPLICATIONS

For use in general purpose rectification of power supplies, inverters, converters and freewheeling diodes application.

Note

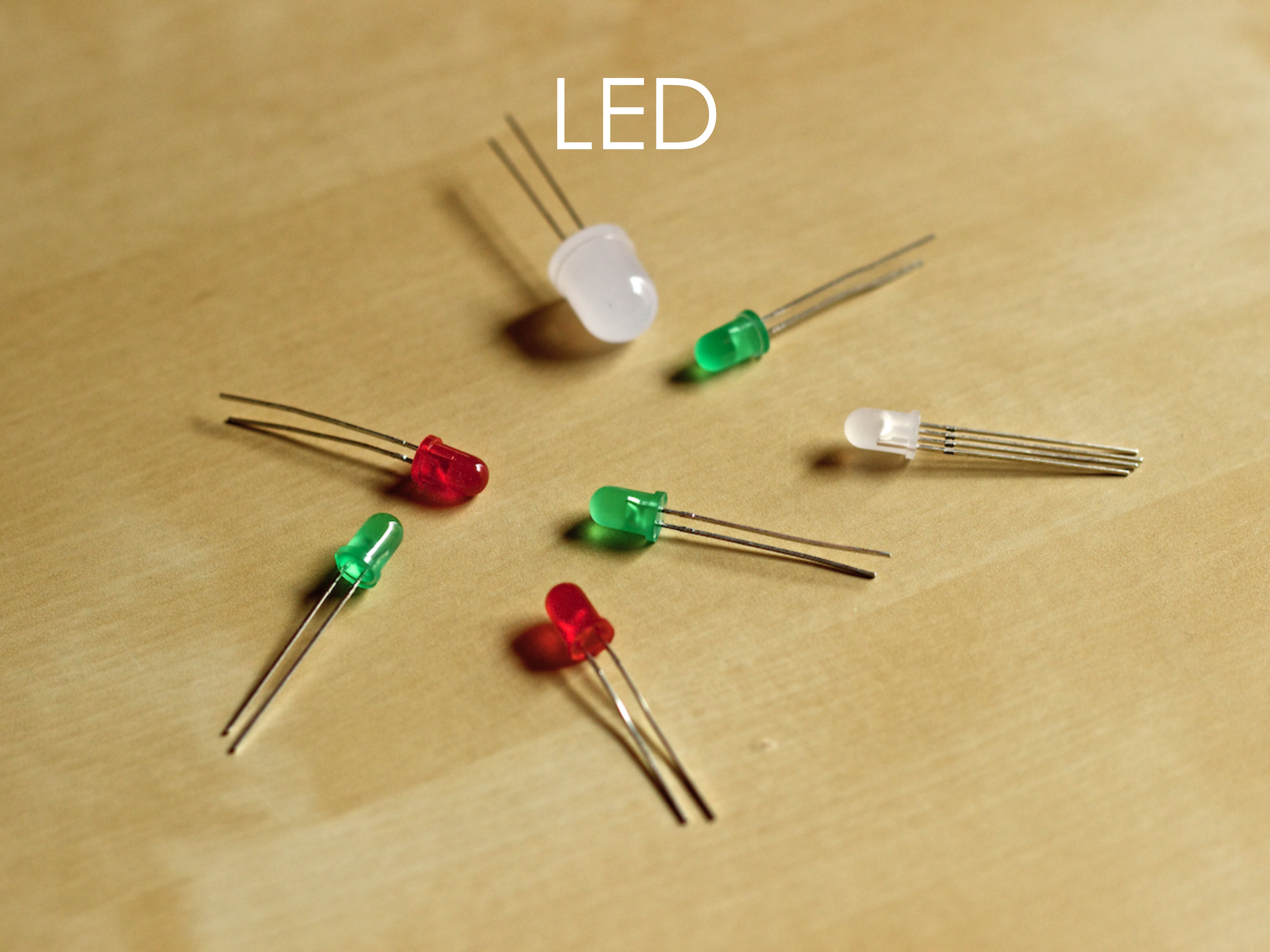
- These devices are not AEC-Q101 qualified.

MECHANICAL DATA

Case: DO-204AL, molded epoxy body
Molding compound meets UL 94 V-0 flammability rating
Base P/N-E3 - RoHS compliant, commercial grade

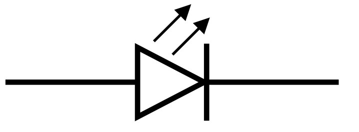
Terminals: Matte tin plated leads, solderable per J-STD-002 and JESD 22-B102
E3 suffix meets JESD 201 class 1A whisker test

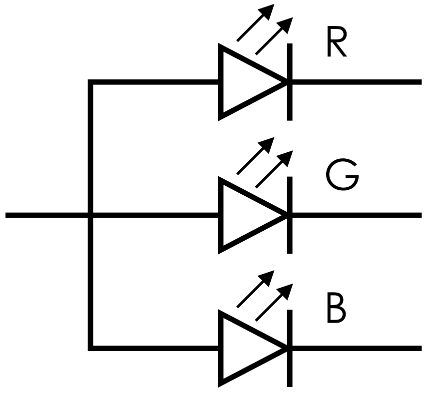
Polarity: Color band denotes cathode end


LED

LED

- Diode qui émet de la lumière dans le sens passant
- Nombreuses couleurs disponibles
- Infra-rouge/Ultra-violet
- RGB





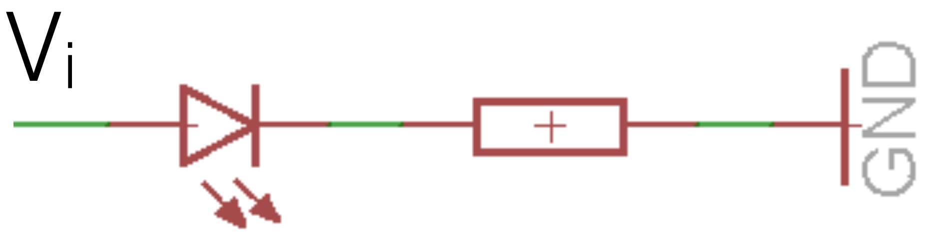
LED

$V_i = V_{LED} + V_R$

$V_i = V_{LED} + i_R \times R$

$V_i = V_{LED} + i_{LED} \times R$

$$R = \frac{V_i - V_{LED}}{i_{LED}}$$



Absolute Maximum Ratings at $T_A = 25°C$

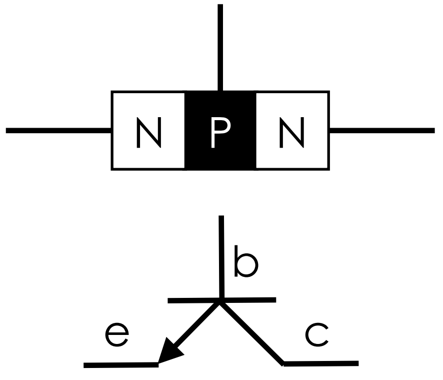
Parameter	Value
Peak Forward Current[1,2]	300 mA
Average Forward Current[2]	20 mA
DC Current[3]	30 mA
Power Dissipation	87 mW
Reverse Voltage ($I_R = 100\ \mu A$)	5 V
Transient Forward Current (10 μs Pulse)[4]	500 mA
LED Junction Temperature	110°C
Operating Temperature Range	-20 to +100°C
Storage Temperature Range	-40 to +100°C

Electrical/Optical Characteristics at $T_A = 25°C$

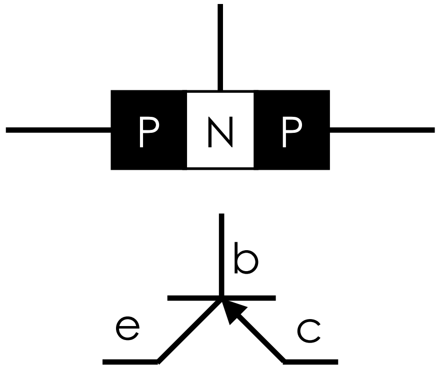
Symbol	Description	Min.	Typ.	Max.	Unit	Test Condition
V_F	Forward Voltage		1.8	2.2	V	$I_F = 20$ mA
V_R	Reverse Breakdown Voltage	5.0	15.0		V	$I_R = 100\ \mu A$
λ_p	Peak Wavelength		645		nm	Measurement at Peak
λ_d	Dominant Wavelength		637		nm	Note 1
$\Delta\lambda^1/_2$	Spectral Line Halfwidth		20		nm	
τ_S	Speed of Response		30		ns	Exponential Time Constant, e^{-t}/T_S
C	Capacitance		30		pF	$V_F = 0$, f = 1 MHz
$R\theta_{J\text{-}PIN}$	Thermal Resistance		260[3] 210[4] 290[5]		°C/W	Junction to Cathode Lead
η_V	Luminous Efficacy		80		lm/W	Note 2

Transistor

Transistor



- Assemblage de trois semi-conducteurs
- Activation : **courant** à la base
- **NPN** : base N, collecteur et émetteur P
  - Activé quand la base est plus positive que l’émetteur



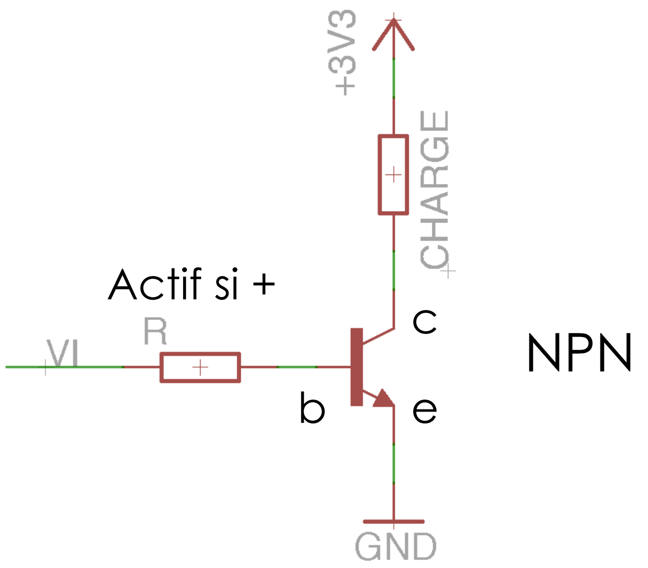
- **PNP** : base P, collecteur et émetteur N
  - Activé quand la base est plus négative que l’émetteur

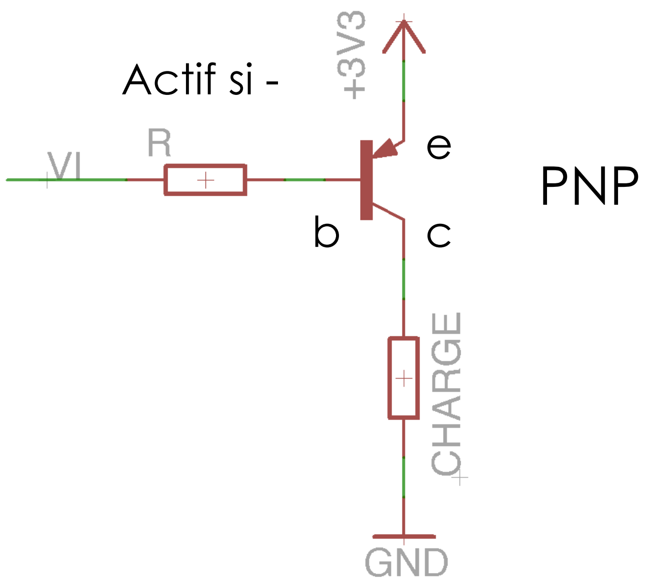
FET

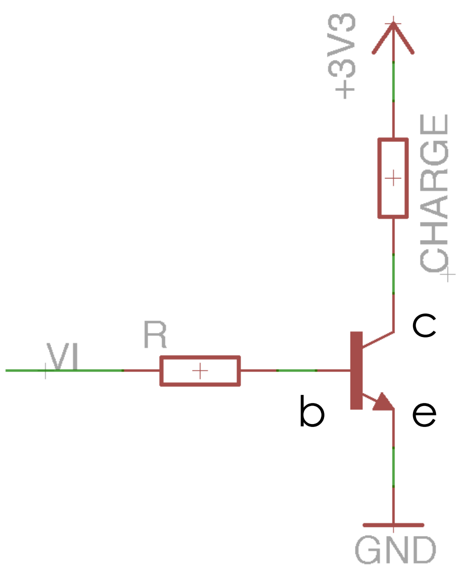
- Transistor à effet de champ
- Activation : **tension** à la base
  + Pas besoin de courant pour activer la porte
  - Plus fragiles que les transistors
- Type N / Type P
  - Base ⇒ grille
  - Collecteur ⇒ source
  - Émetteur ⇒ drain

Applications

- Interrupteur programmable
  - Transistor en mode saturé
  - Contrôler un circuit de puissance avec un circuit logique
- Amplificateur linéaire
  - $i_C = i_b \times h_{FE}$
  - $R_b \approx V_i / (3 \times I_b)$



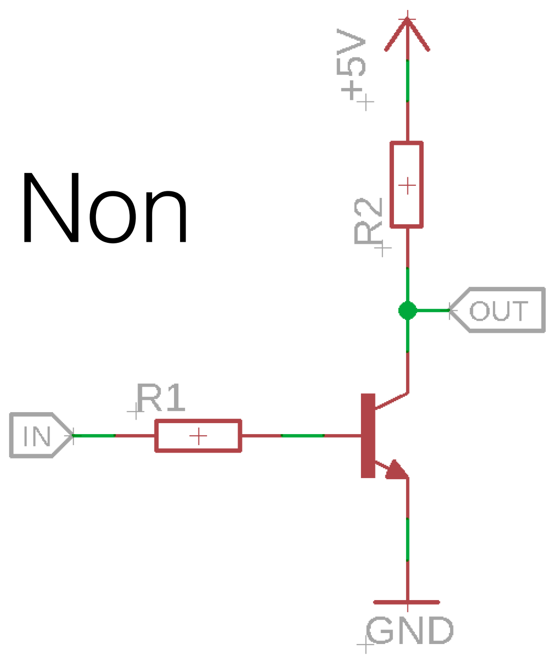




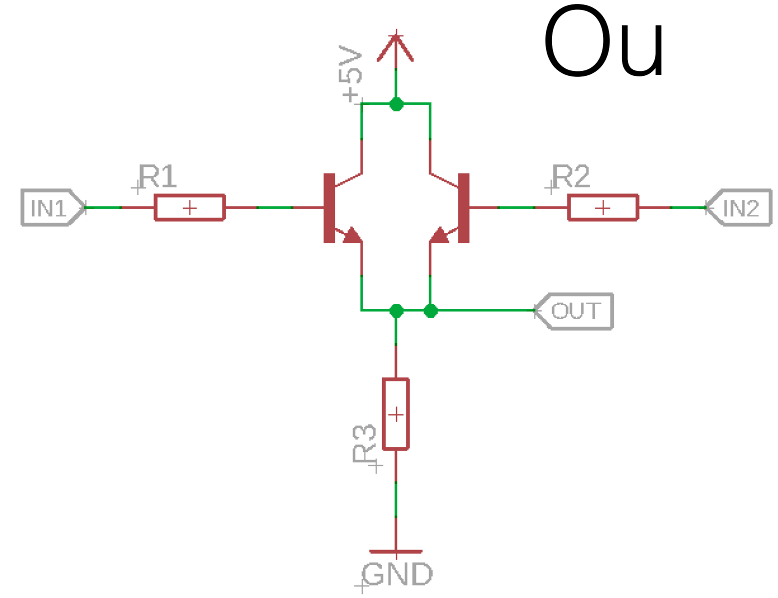
Symbol	Parameter	Conditions	Min.	Max.	Unit
Off Characteristics					
$BV_{(BR)CEO}$	Collector-Emitter Breakdown Voltage[4]	$I_C = 10$ mA, $I_B = 0$	40		V
$BV_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = 10$ µA, $I_E = 0$	75		V
$BV_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = 10$ µA, $I_C = 0$	6.0		V
I_{CEX}	Collector Cut-Off Current	$V_{CE} = 60$ V, $V_{EB(off)} = 3.0$ V		10	nA
I_{CBO}	Collector Cut-Off Current	$V_{CB} = 60$ V, $I_E = 0$		0.01	µA
		$V_{CB} = 60$ V, $I_E = 0$, $T_A = 125°C$		10	
I_{EBO}	Emitter Cut-Off Current	$V_{EB} = 3.0$ V, $I_C = 0$		10	nA
I_{BL}	Base Cut-Off Current	$V_{CE} = 60$ V, $V_{EB(off)} = 3.0$ V		20	nA
On Characteristics					
h_{FE}	DC Current Gain	$I_C = 0.1$ mA, $V_{CE} = 10$ V	35		
		$I_C = 1.0$ mA, $V_{CE} = 10$ V	50		
		$I_C = 10$ mA, $V_{CE} = 10$ V	75		
		$I_C = 10$ mA, $V_{CE} = 10$ V, $T_A = -55°C$	35		
		$I_C = 150$ mA, $V_{CE} = 10$ V[4]	100	300	
		$I_C = 150$ mA, $V_{CE} = 1$ V[4]	50		
		$I_C = 500$ mA, $V_{CE} = 10$ V[4]	40		
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage[4]	$I_C = 150$ mA, $I_B = 15$ mA		0.3	V
		$I_C = 500$ mA, $I_B = 50$ mA		1.0	
$V_{BE(sat)}$	Base-Emitter Saturation Voltage[4]	$I_C = 150$ mA, $I_B = 15$ mA	0.6	1.2	V
		$I_C = 500$ mA, $I_B = 50$ mA		2.0	

Portes logiques

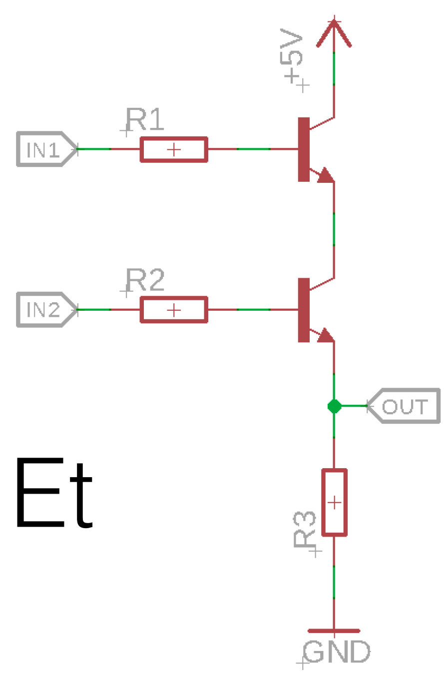
Non



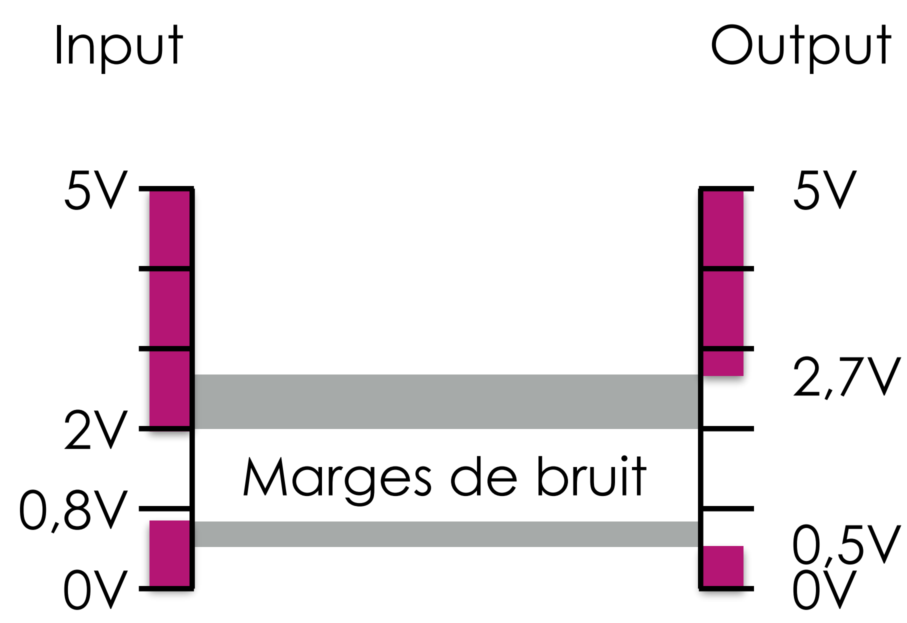
Ou



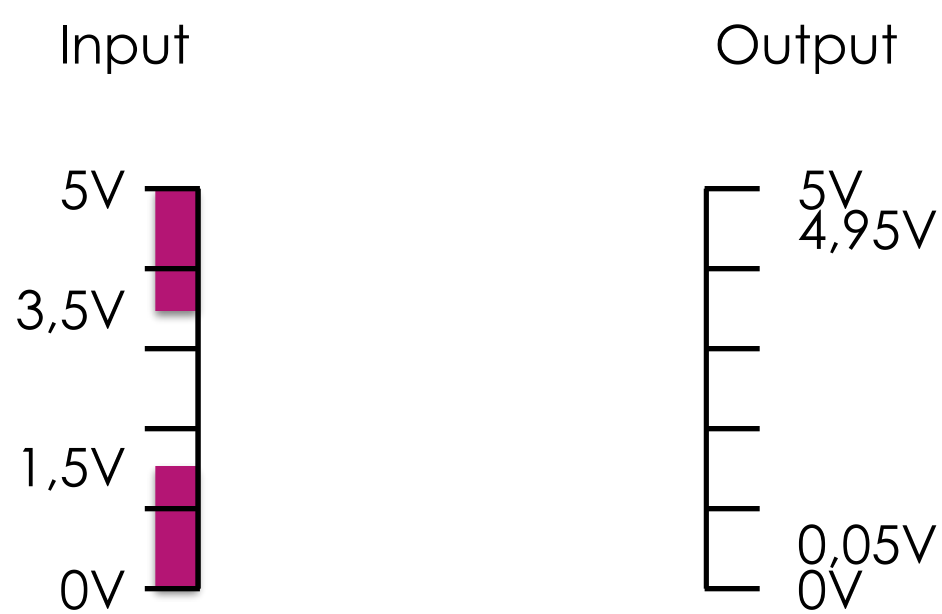
Et



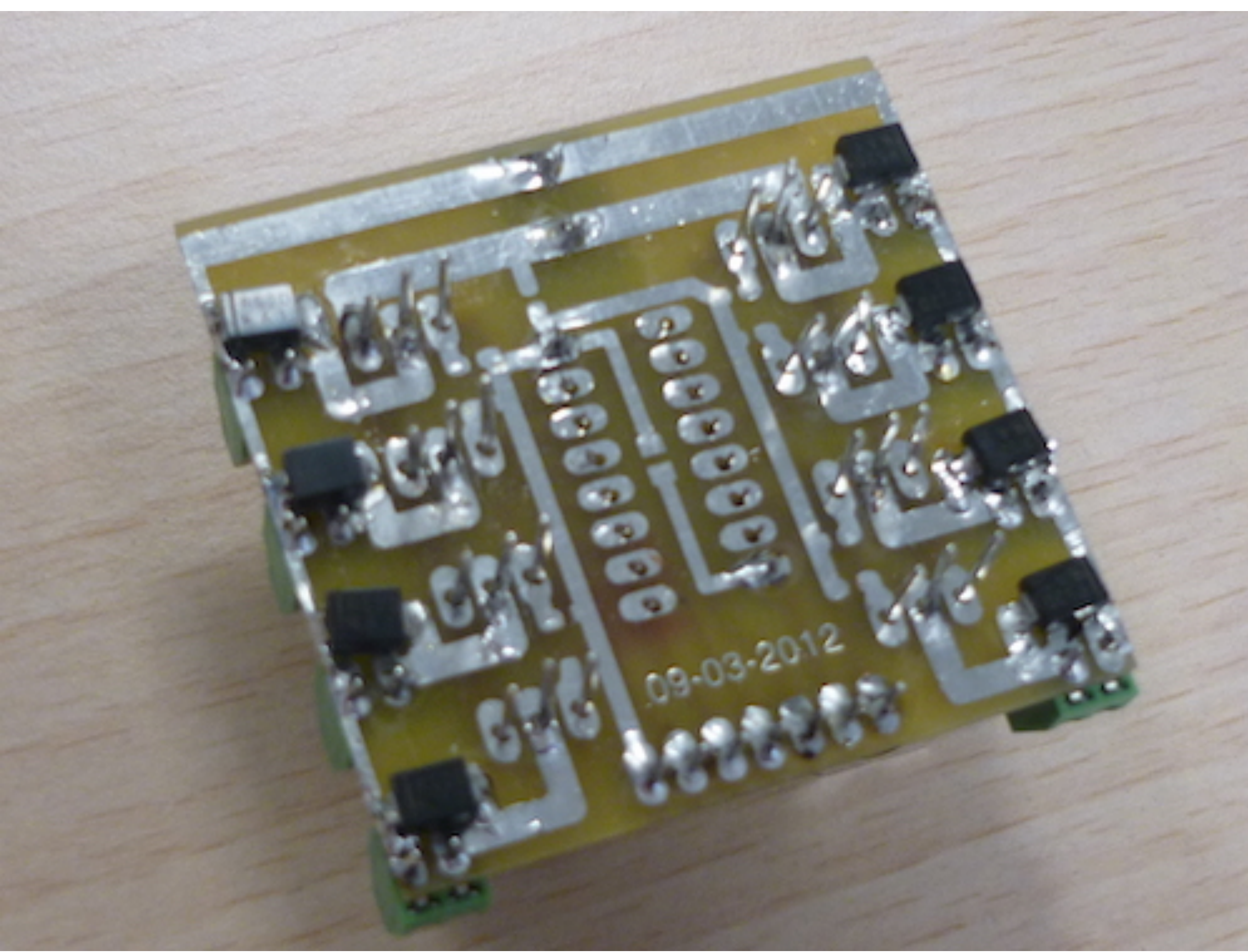
Norme TTL

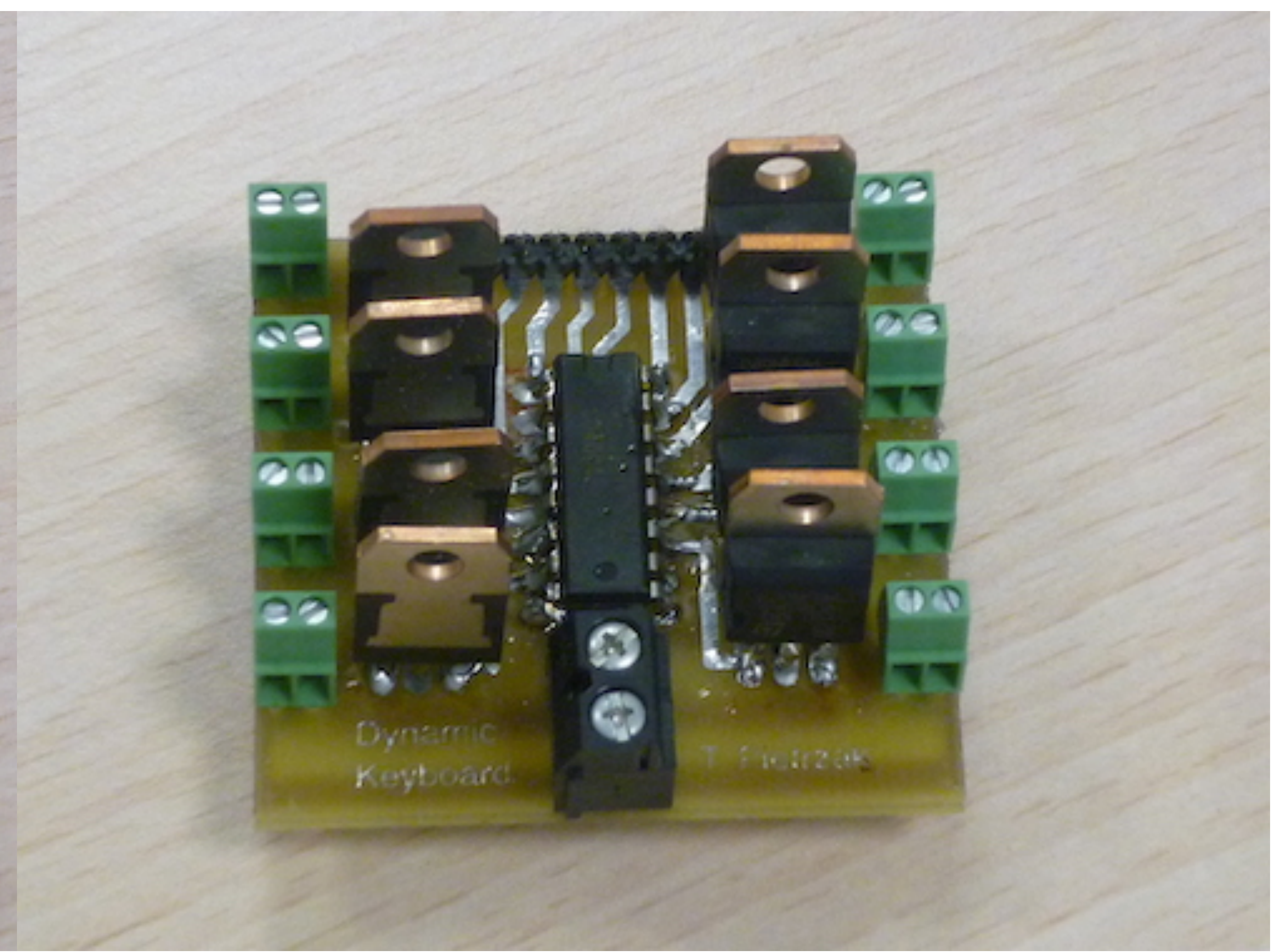


Norme CMOS



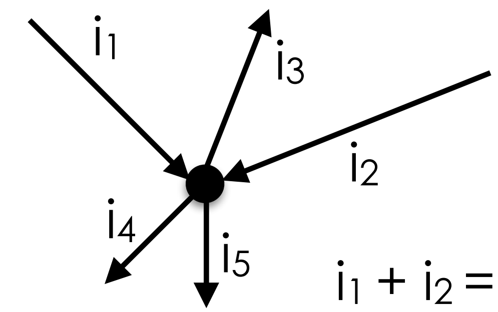
Résolution de circuit





Lois de Kirchhoff

Loi des nœuds



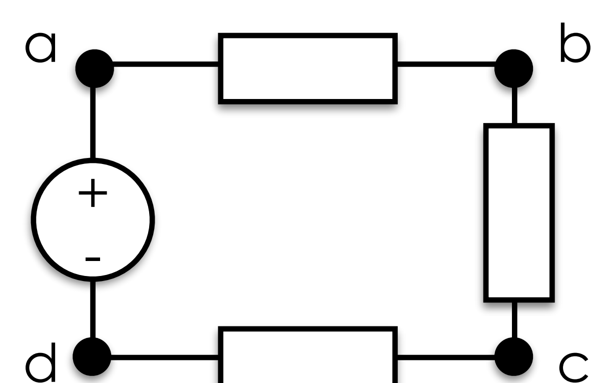
$$i_1 + i_2 = i_3 + i_4 + i_5$$

La somme des intensités des courants qui entrent par un nœud est égale à la somme des intensités des courants qui sortent du même nœud.

Loi des mailles

Dans une maille la somme algébrique des différences de potentiel est constamment nulle.

$$U_{ab} + U_{bc} + U_{cd} + U_{da} = 0$$



Méthode tension de nœuds

- Choisir une référence : la masse
- Donner un nom aux autres voltages de nœuds
- Résoudre les nœuds faciles en premier
- Écrire les lois de Kirchhoff pour chaque nœud
- Résoudre le système d’équations pour toutes les tensions de nœuds
- Résoudre les courants avec la loi d’Ohm

Exemple

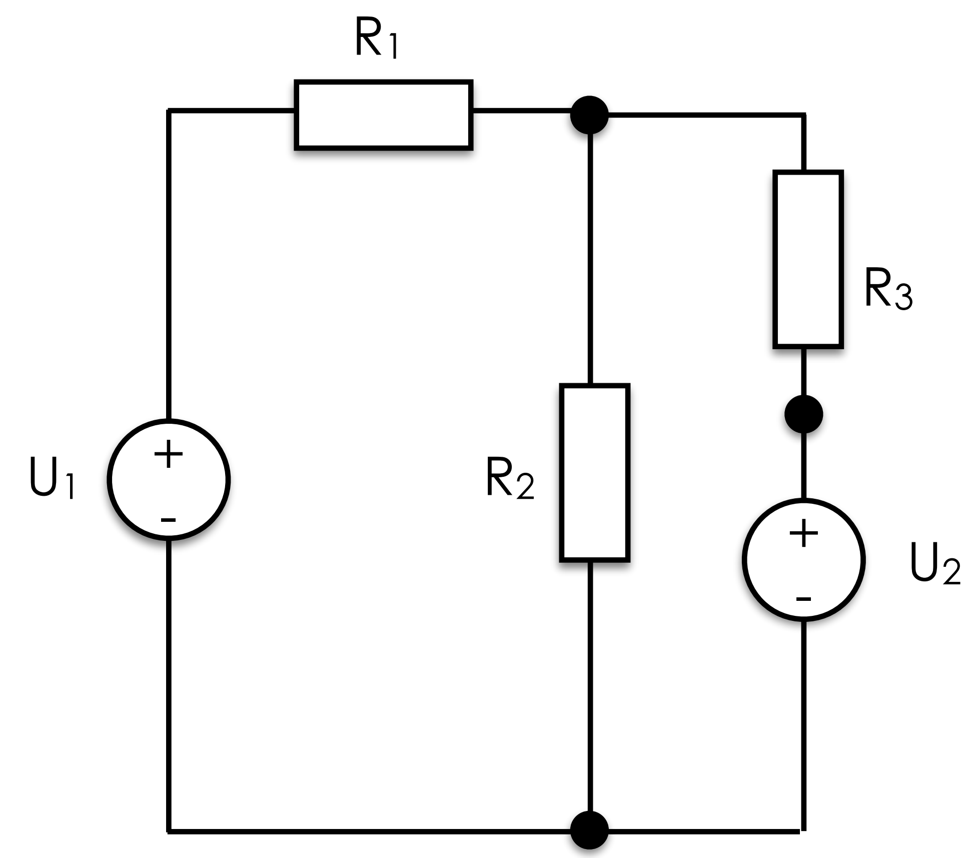
$U_1 = 15V$

U2 = 5V

$R_1 = 15\Omega$

$R_2 = 20\Omega$

$R_3 = 60\Omega$



Exemple

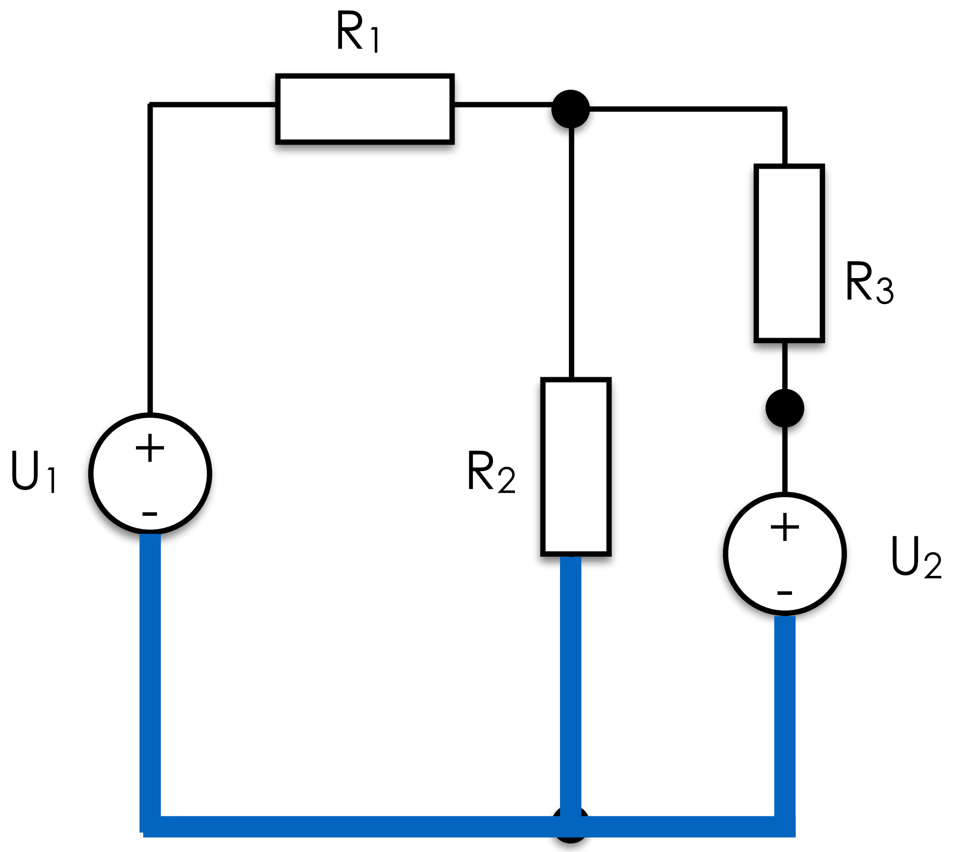
$U_1 = 15V$

U2 = 5V

$R_1 = 15\Omega$

$R_2 = 20\Omega$

$R_3 = 60\Omega$



Exemple

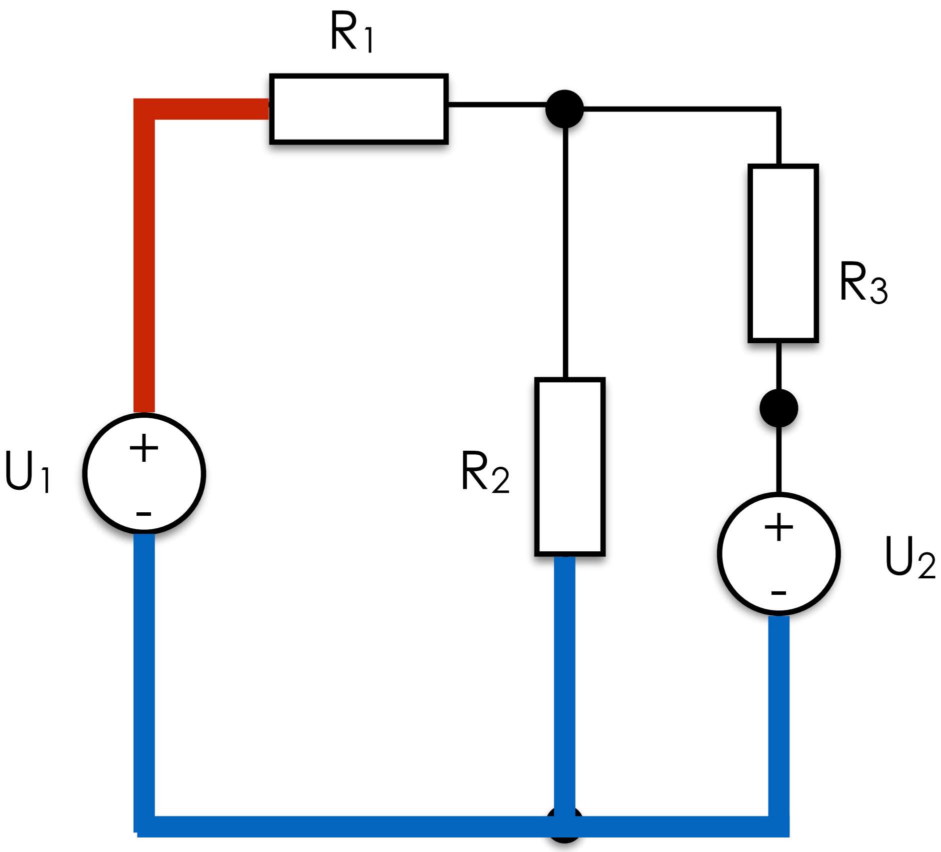
$U_1 = 15V$

$U2 = 5V$

$R_1 = 15\Omega$

$R_2 = 20\Omega$

$R_3 = 60\Omega$



Exemple

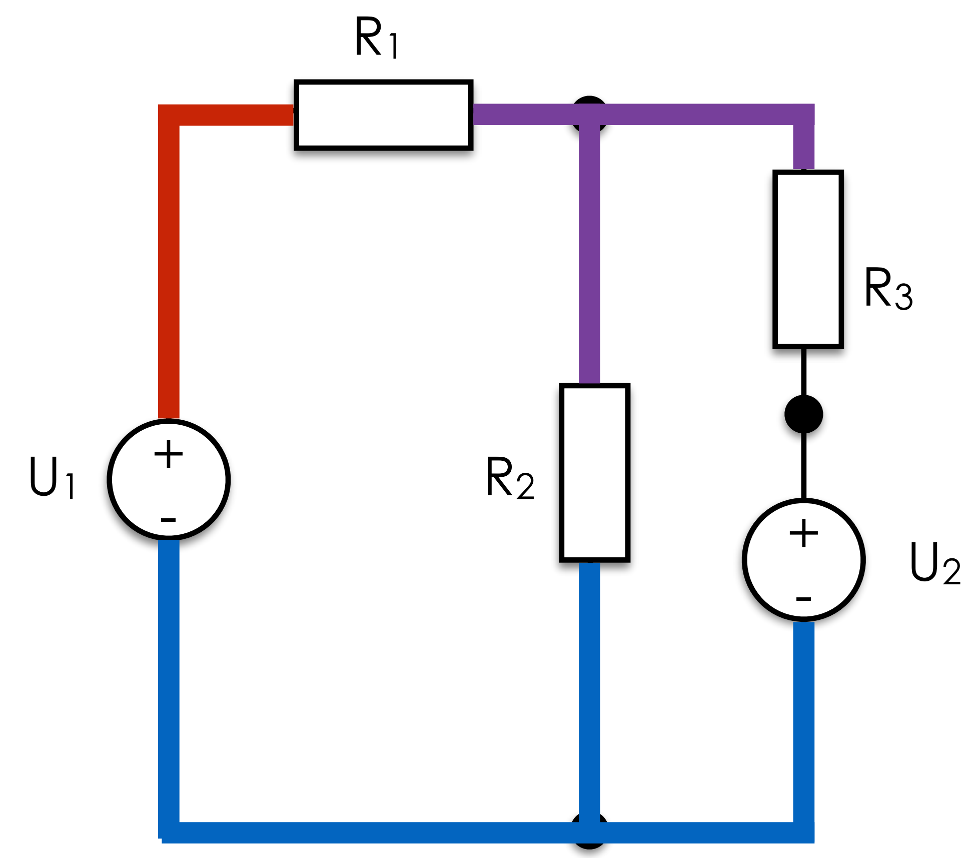
$U_1 = 15V$

U2 = 5V

$R_1 = 15\Omega$

$R_2 = 20\Omega$

$R_3 = 60\Omega$



Exemple

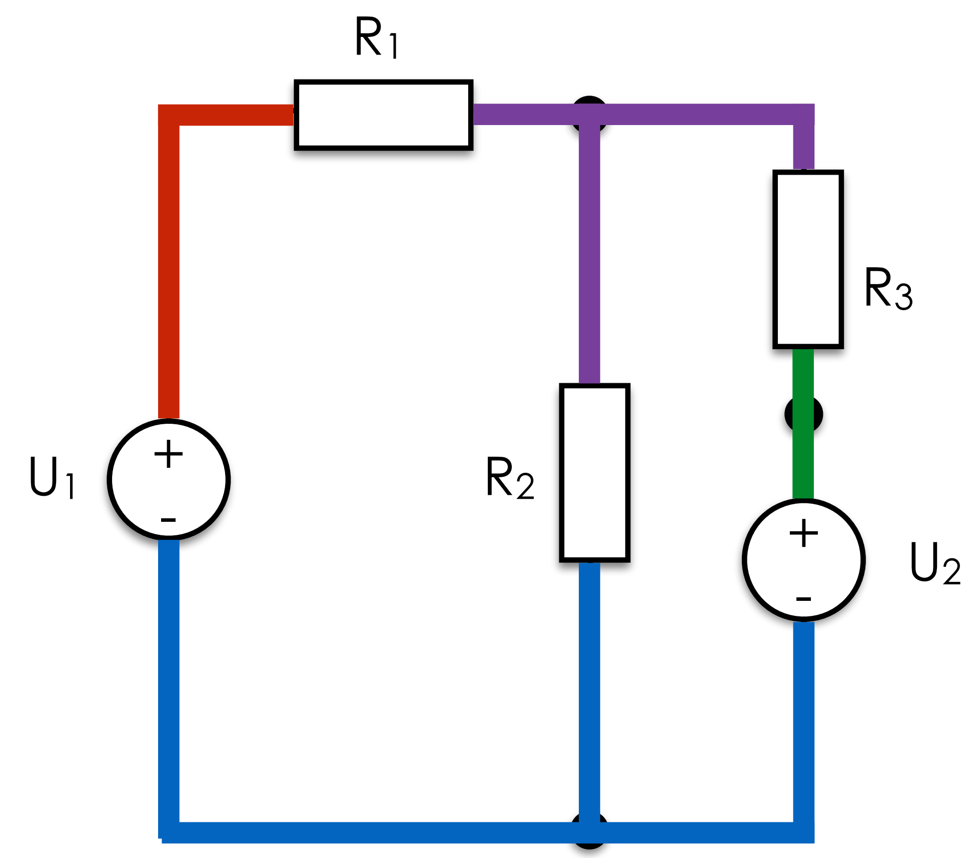
$U_1 = 15V$

U2 = 5V

$R_1 = 15\Omega$

$R_2 = 20\Omega$

$R_3 = 60\Omega$



Exemple

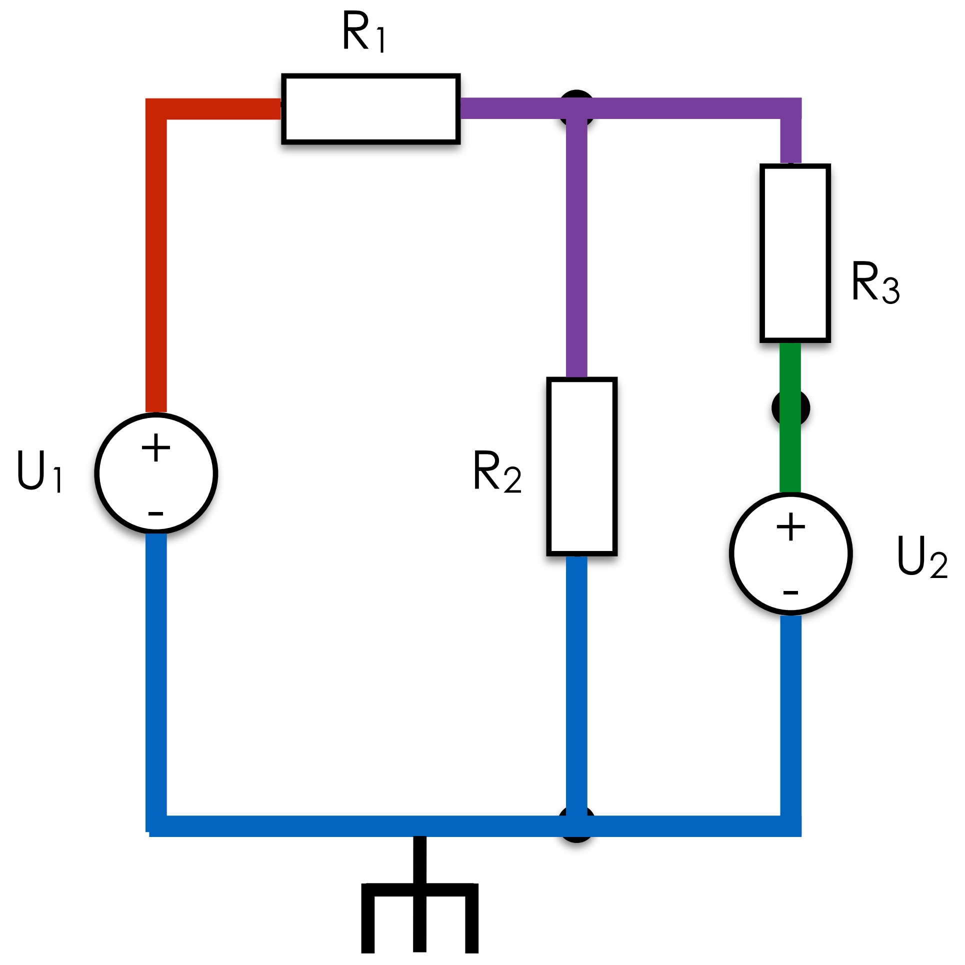
$U_1 = 15V$

U2 = 5V

$R_1 = 15\Omega$

$R_2 = 20\Omega$

$R_3 = 60\Omega$



Exemple

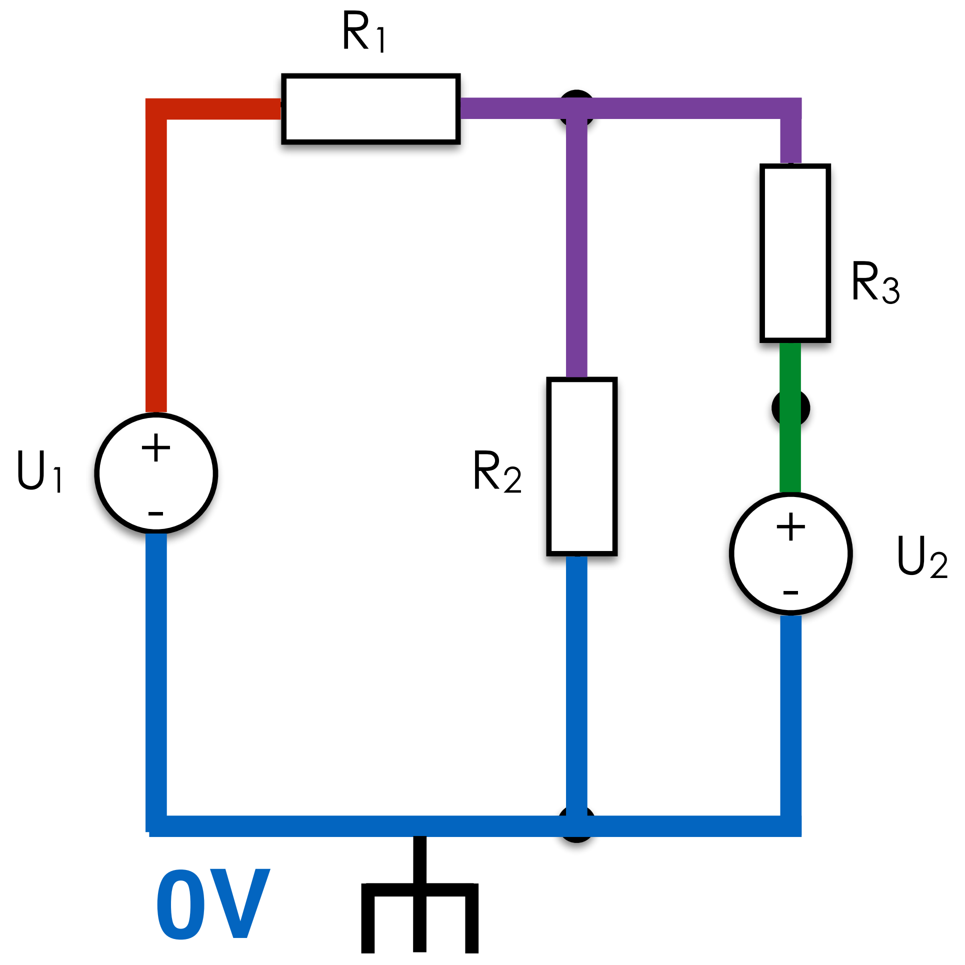
$U_1 = 15V$

U2 = 5V

$R_1 = 15\Omega$

$R_2 = 20\Omega$

$R_3 = 60\Omega$



Exemple

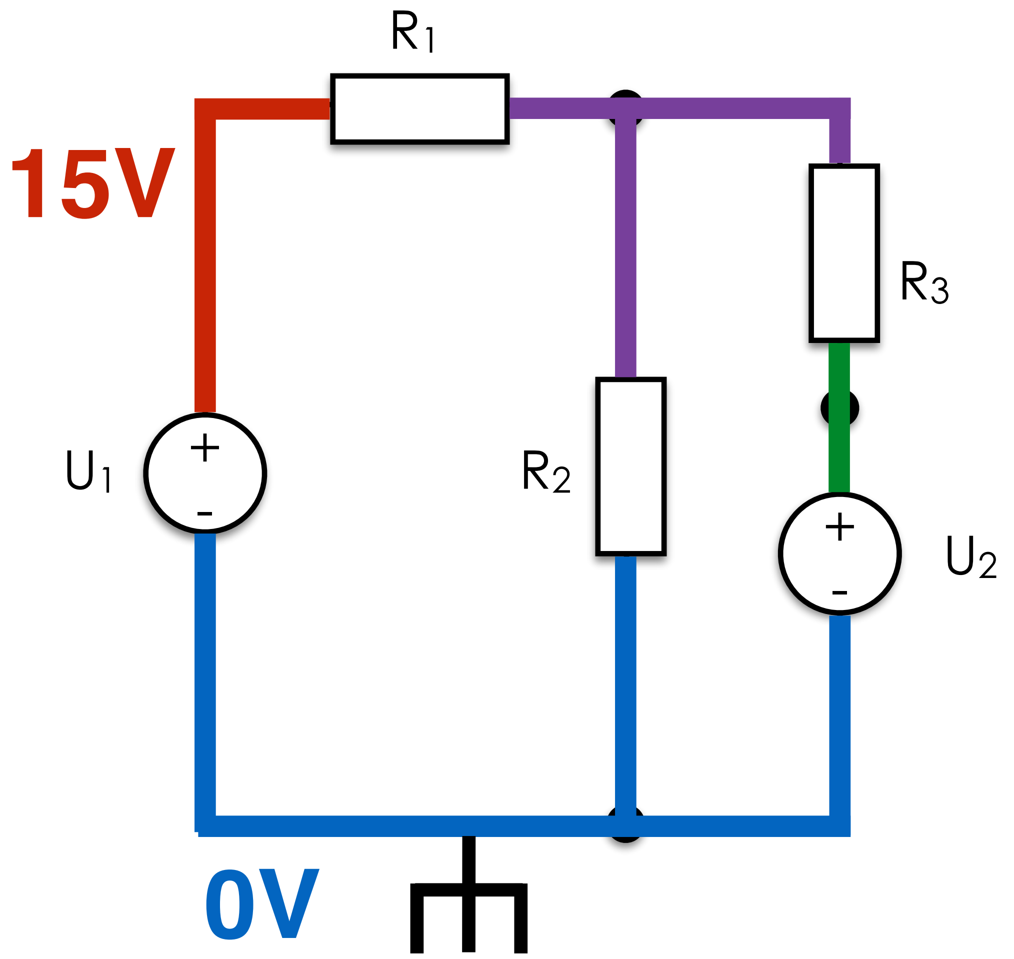
$U_1 = 15V$

U2 = 5V

$R_1 = 15\Omega$

$R_2 = 20\Omega$

$R_3 = 60\Omega$



Exemple

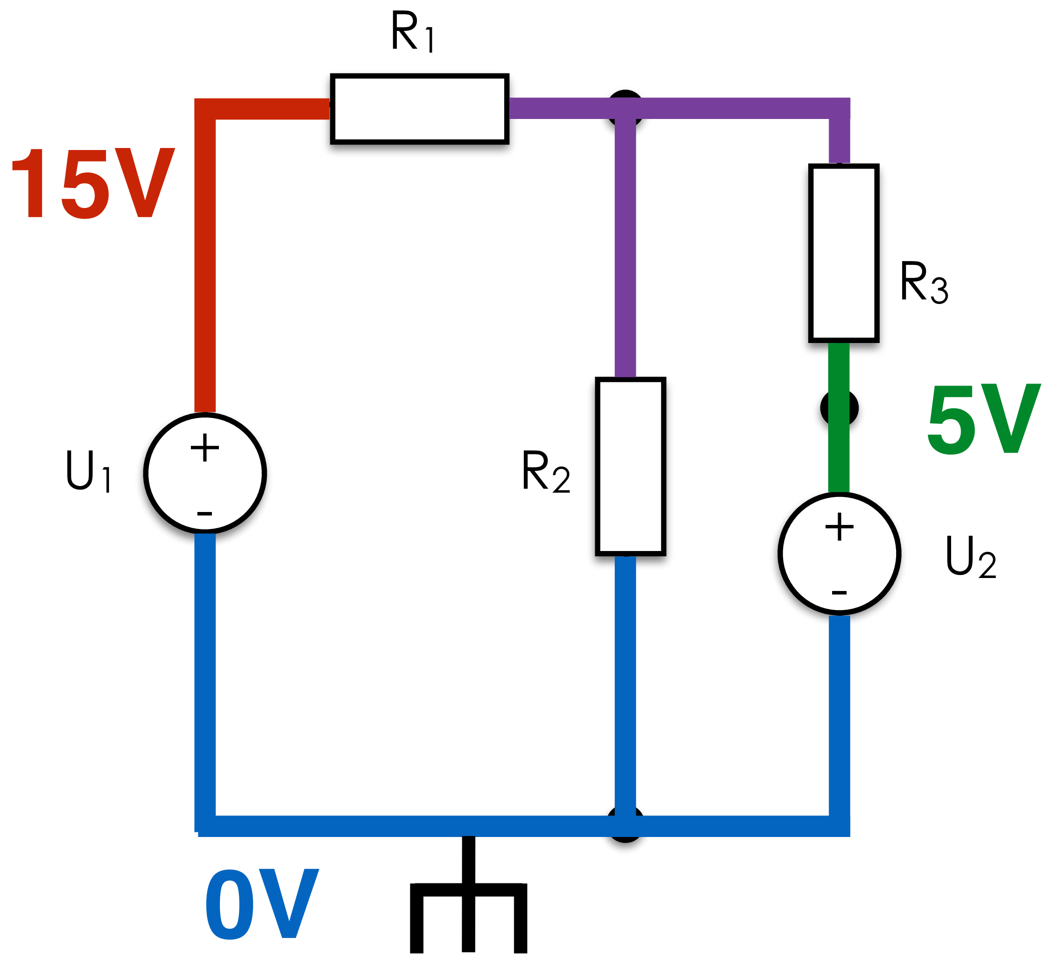
$U_1 = 15V$

$U2 = 5V$

$R_1 = 15\Omega$

$R_2 = 20\Omega$

$R_3 = 60\Omega$



Exemple

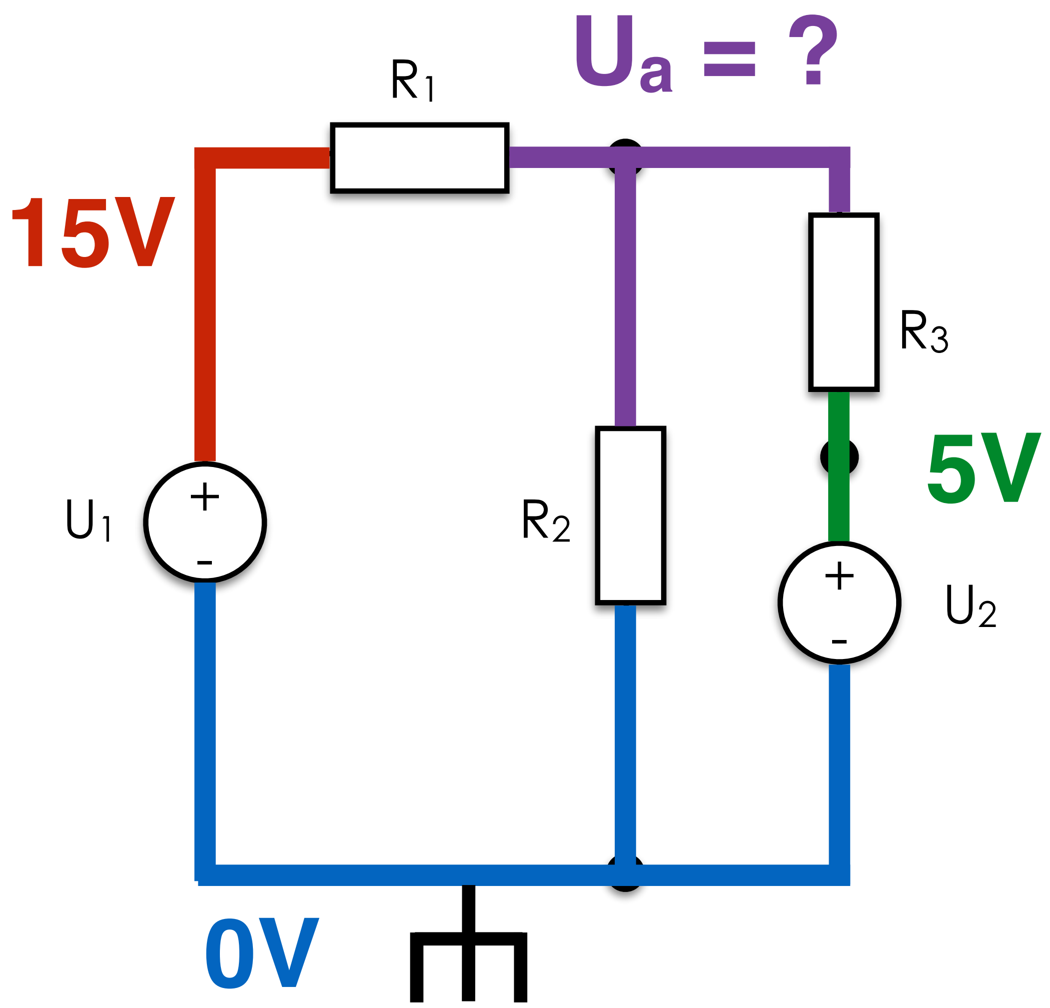
$U_1 = 15V$

$U2 = 5V$

$R_1 = 15\Omega$

$R_2 = 20\Omega$

$R_3 = 60\Omega$



Exemple

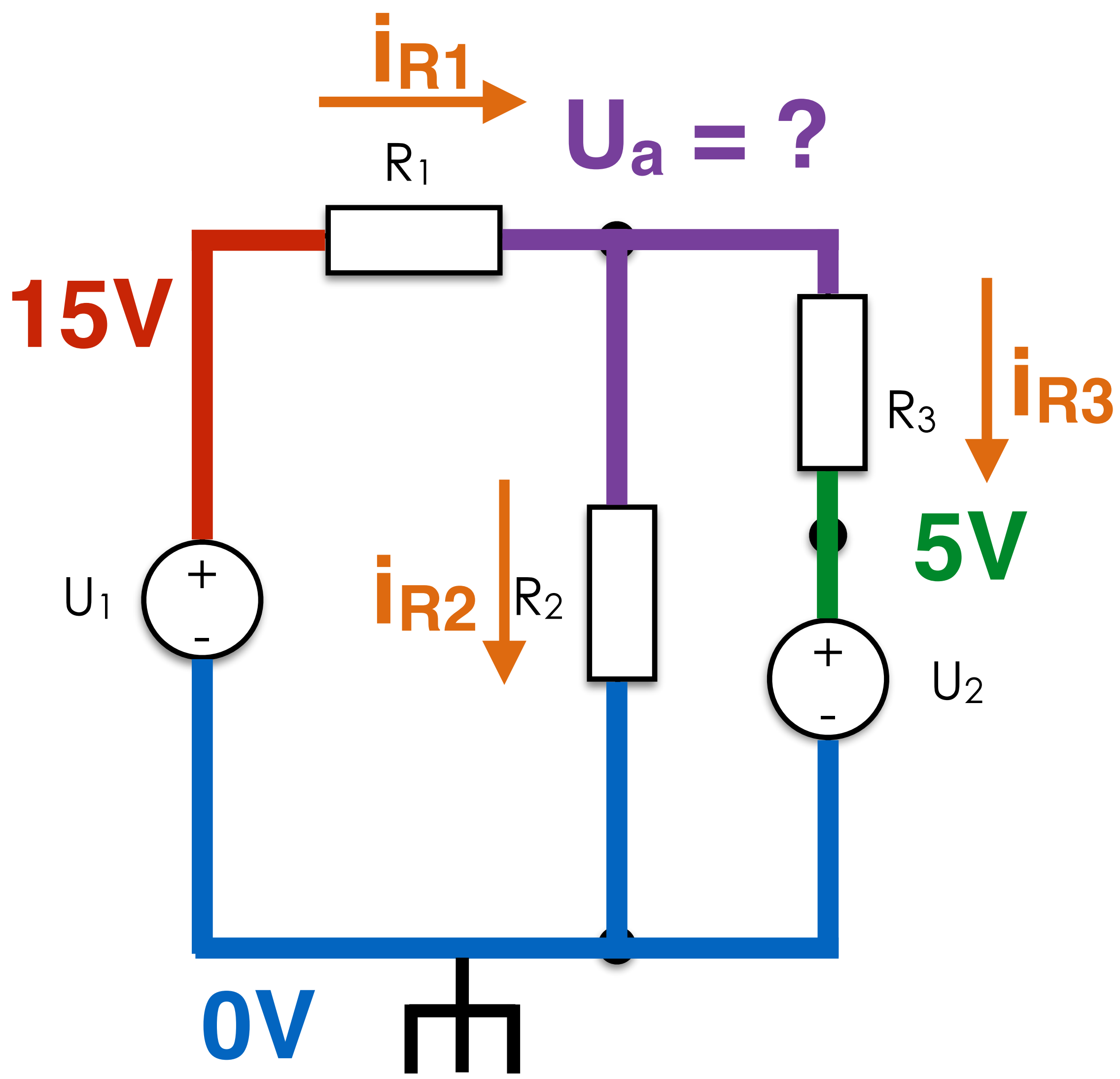
$U_1 = 15V$

$U2 = 5V$

$R_1 = 15\Omega$ $i_{R1} = (15 - U_a) / 15$

$R_2 = 20\Omega$ $i_{R2} = U_a / 20$

$R_3 = 60\Omega$ $i_{R3} = (U_a - 5) / 60$



Exemple

$U_1 = 15V$

$U2 = 5V$

$R_1 = 15\Omega$ $i_{R1} = (15 - U_a) / 15$

$R_2 = 20\Omega$ $i_{R2} = U_a / 20$

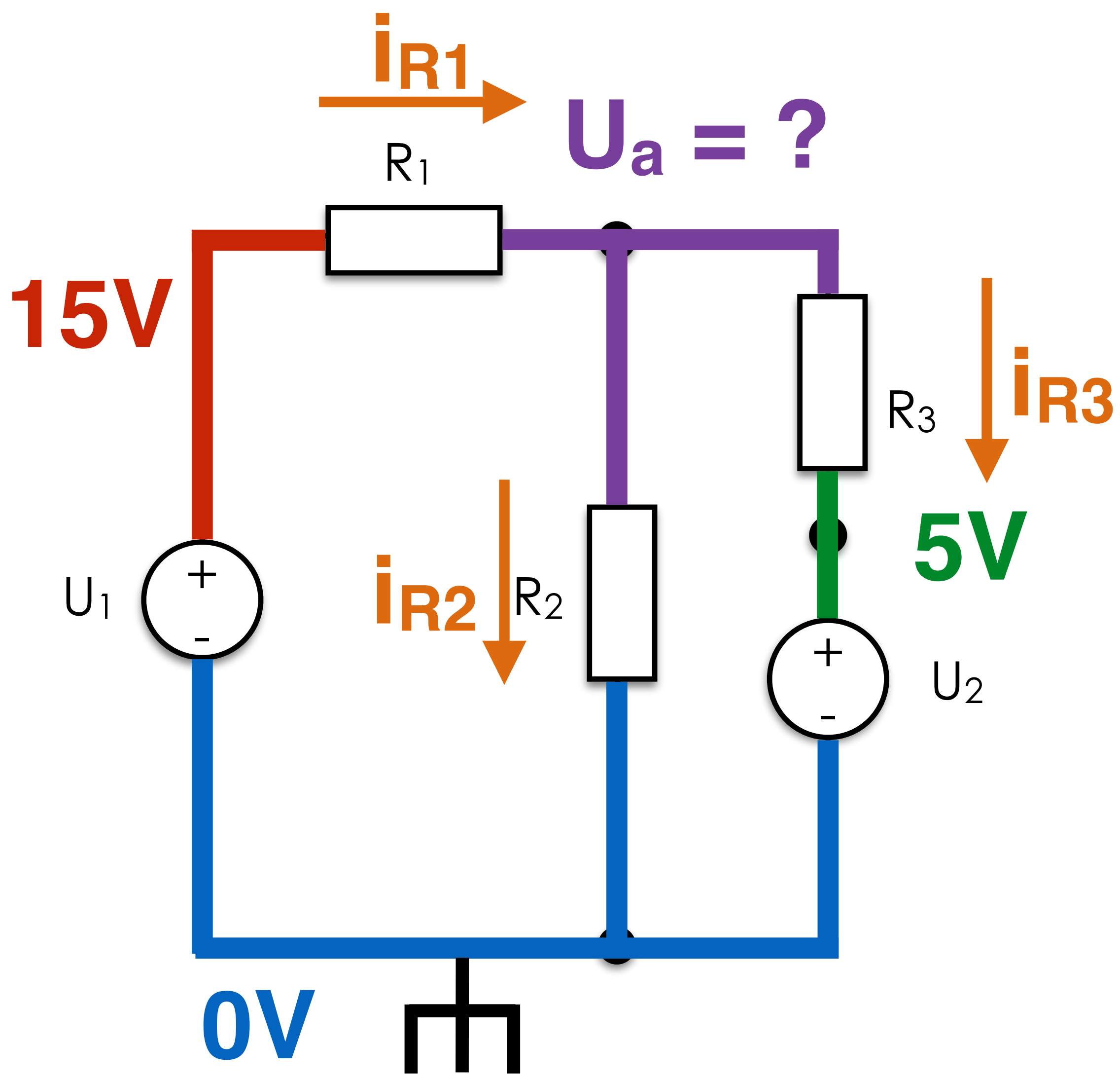
$R_3 = 60\Omega$ $i_{R3} = (U_a - 5) / 60$

$(15 - U_a) / 15 = U_a / 20 + (U_a - 5) / 60$

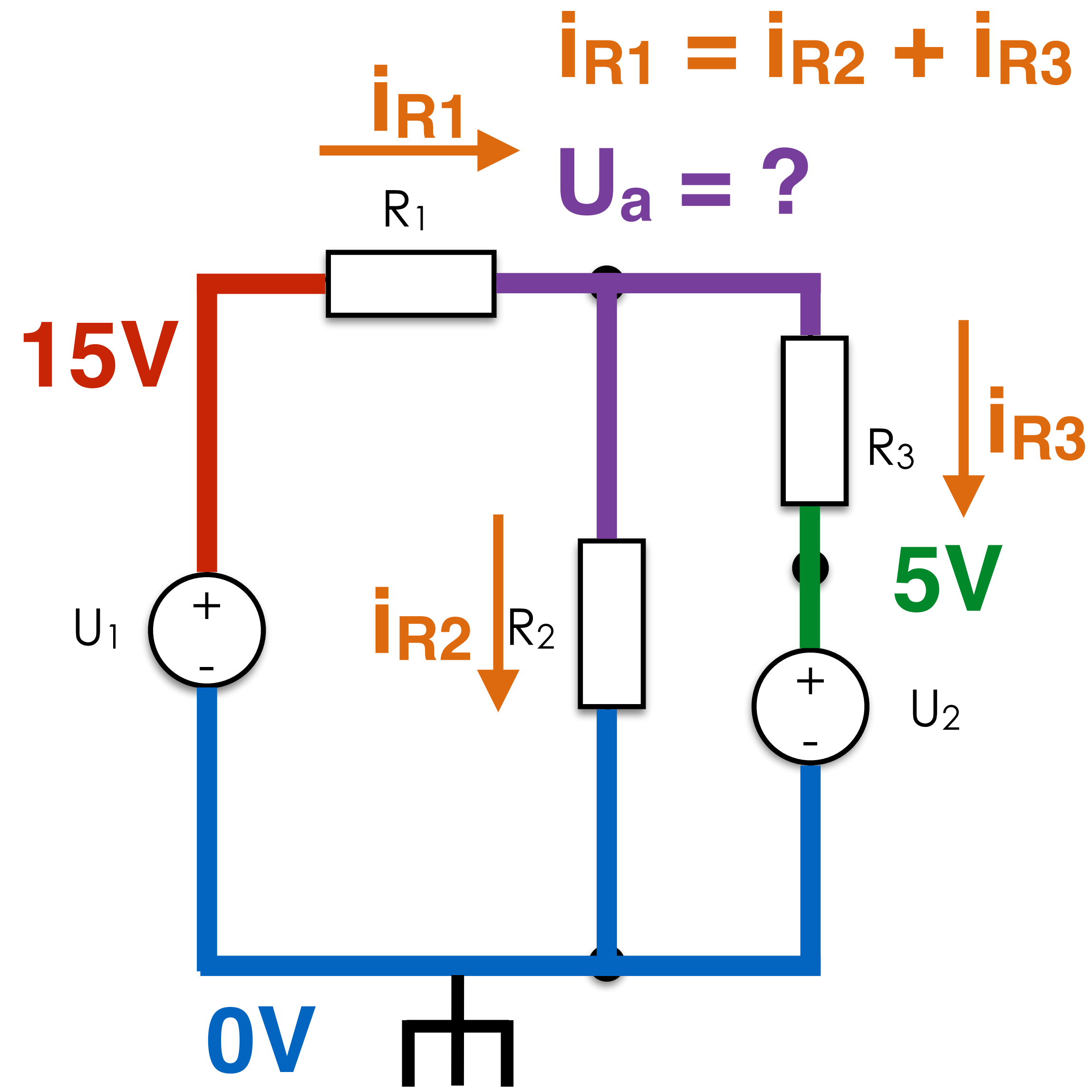
$4 \times (15 - U_a) = 3\ U_a + U_a - 5$

$60 - 4\ U_a = 4\ U_a - 5$

$8\ U_a = 65$



Exemple



$U_1 = 15V$

$U2 = 5V$

$R_1 = 15\Omega$ $i_{R1} = (15 - U_a) / 15$

$R_2 = 20\Omega$ $i_{R2} = U_a / 20$

$R_3 = 60\Omega$ $i_{R3} = (U_a - 5) / 60$

$(15 - U_a) / 15 = U_a / 20 + (U_a - 5) / 60$

$4 \times (15 - U_a) = 3 U_a + U_a - 5$

$60 - 4 U_a = 4 U_a - 5$

$8 U_a = 65$

Exemple

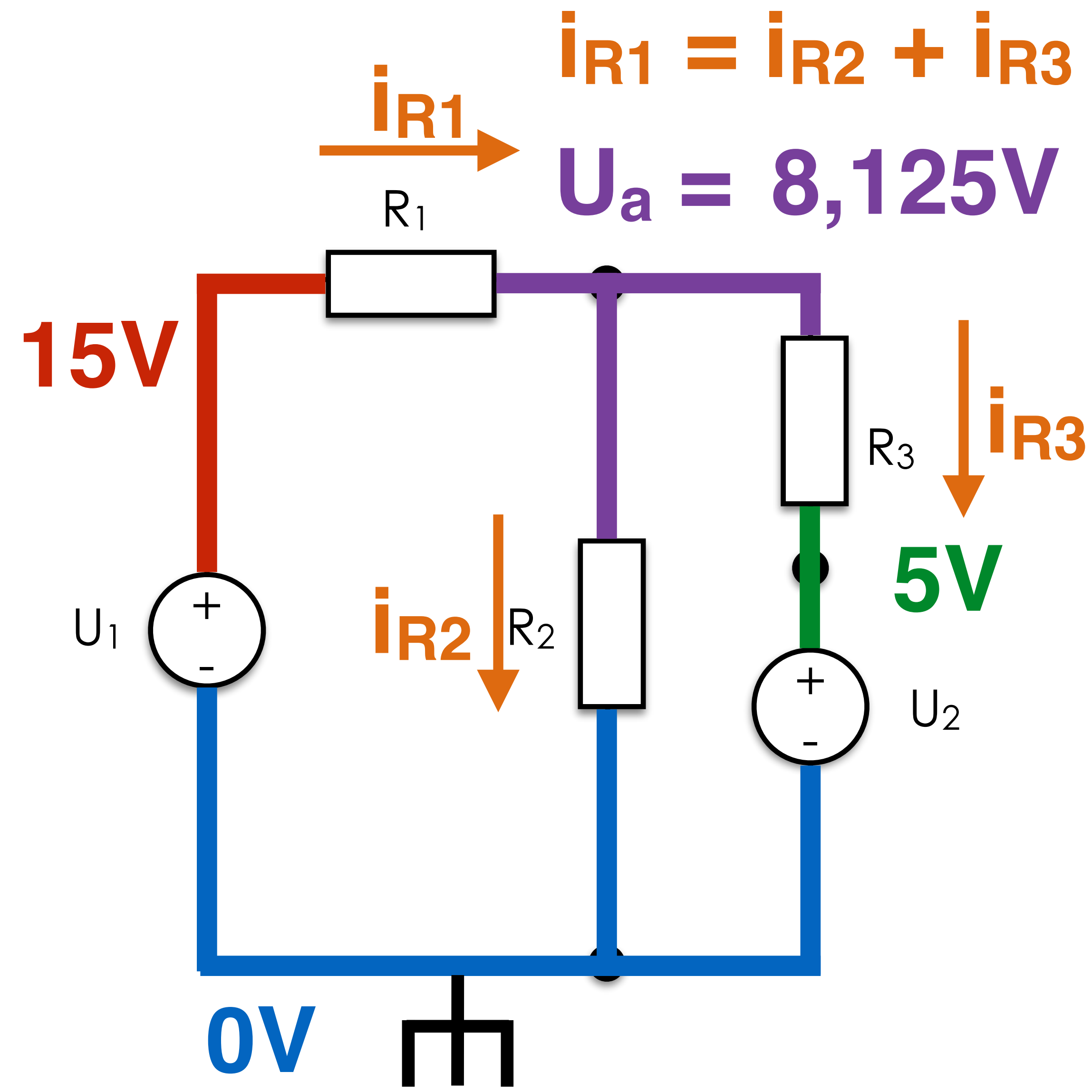
$U_1 = 15V$

$U2 = 5V$

$R_1 = 15\Omega$ $i_{R1} = (15 - U_a) / 15$

$R_2 = 20\Omega$ $i_{R2} = U_a / 20$

$R_3 = 60\Omega$ $i_{R3} = (U_a - 5) / 60$



$(15 - U_a) / 15 = U_a / 20 + (U_a - 5) / 60$

$4 \times (15 - U_a) = 3\ U_a + U_a - 5$

$60 - 4\ U_a = 4\ U_a - 5$

$8\ U_a = 65$

$U_a = 8{,}125V$

Exemple

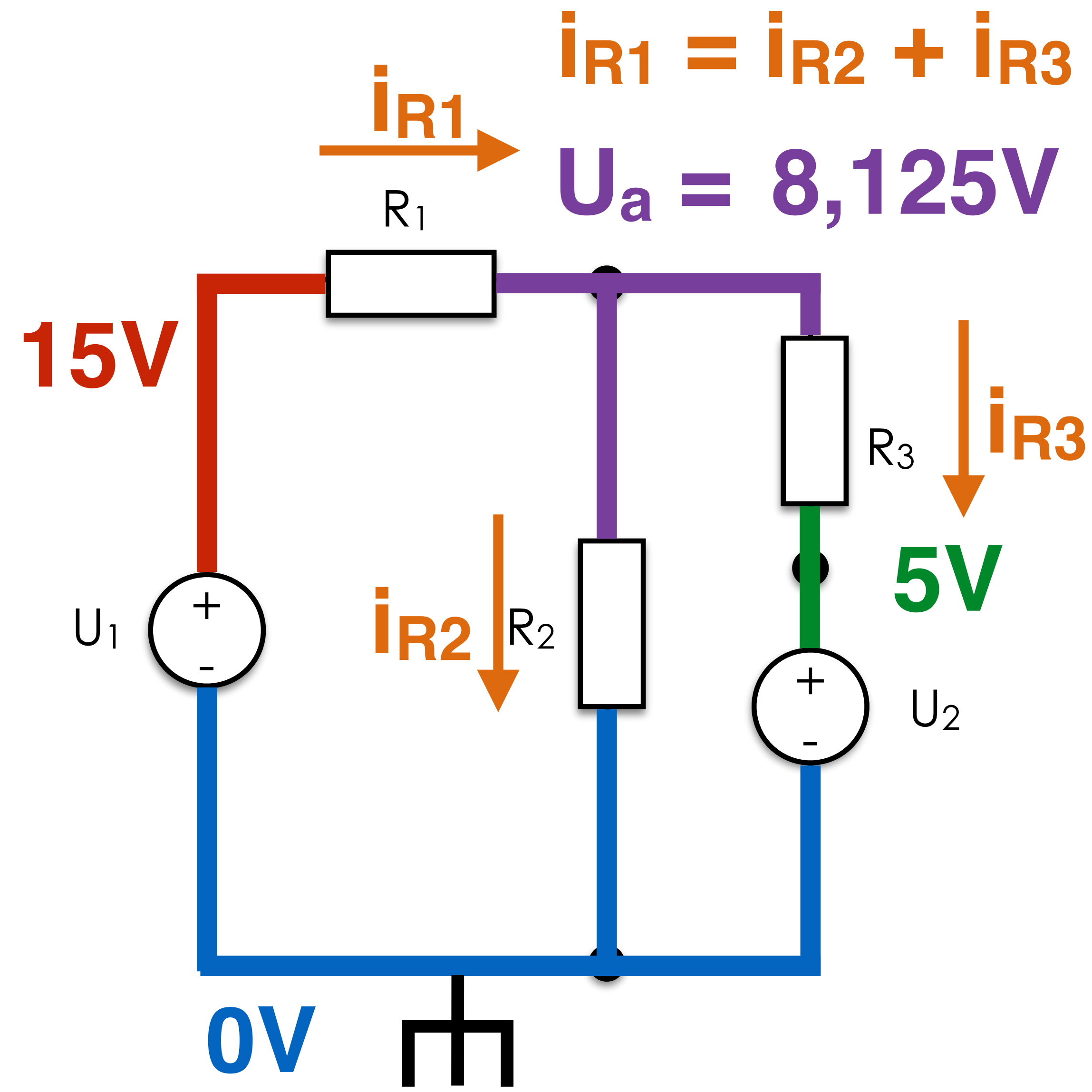
$U_1 = 15V$

$U2 = 5V$

$R_1 = 15\Omega$ $i_{R1} = (15 - U_a) / 15$ $= 0{,}45A$

$R_2 = 20\Omega$ $i_{R2} = U_a / 20$ $= 0{,}40A$

$R_3 = 60\Omega$ $i_{R3} = (U_a - 5) / 60$ $= 0{,}05A$



$(15 - U_a) / 15 = U_a / 20 + (U_a - 5) / 60$

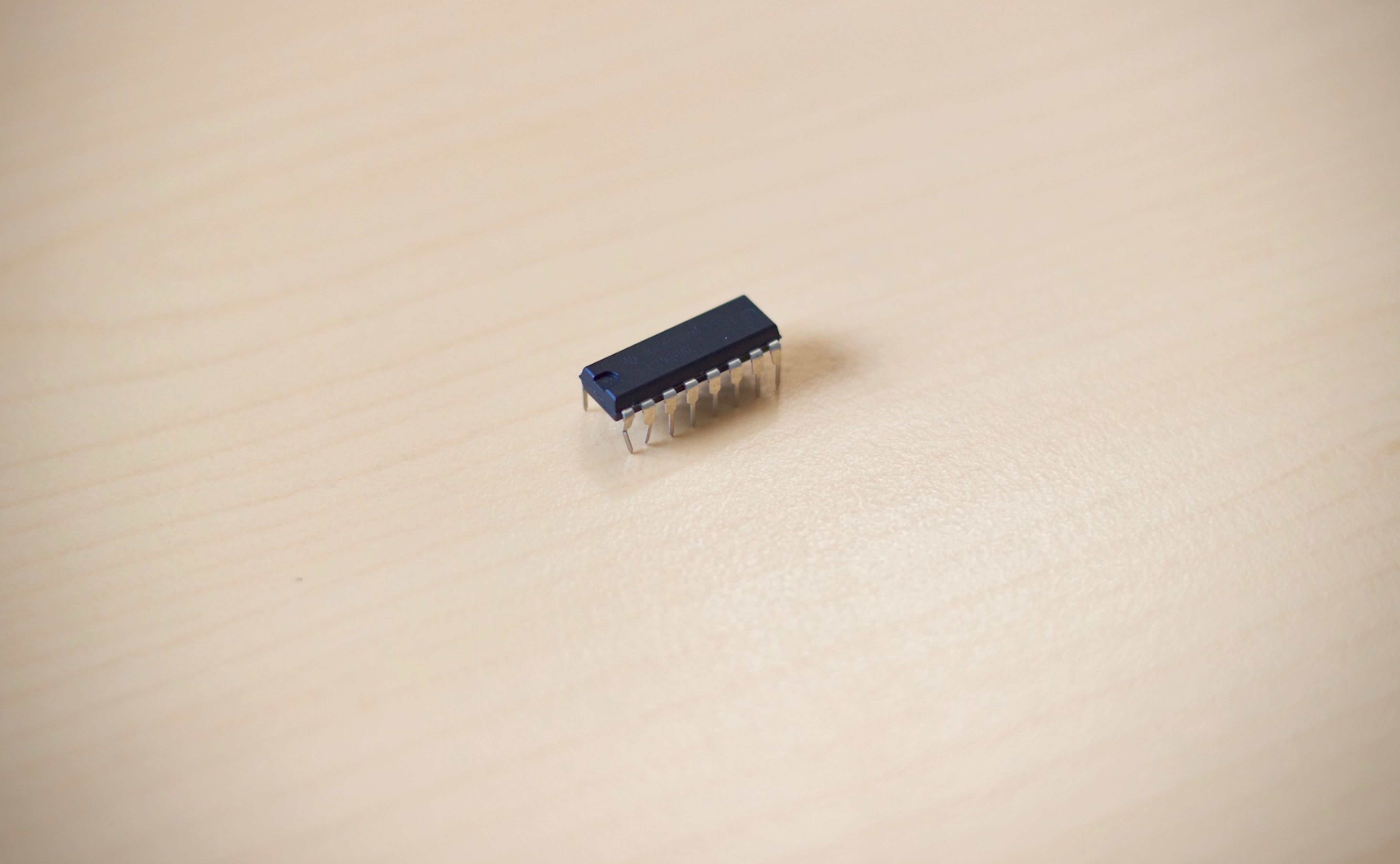
$4 \times (15 - U_a) = 3\ U_a + U_a - 5$

$60 - 4\ U_a = 4\ U_a - 5$

$8\ U_a = 65$

$U_a = 8{,}125V$

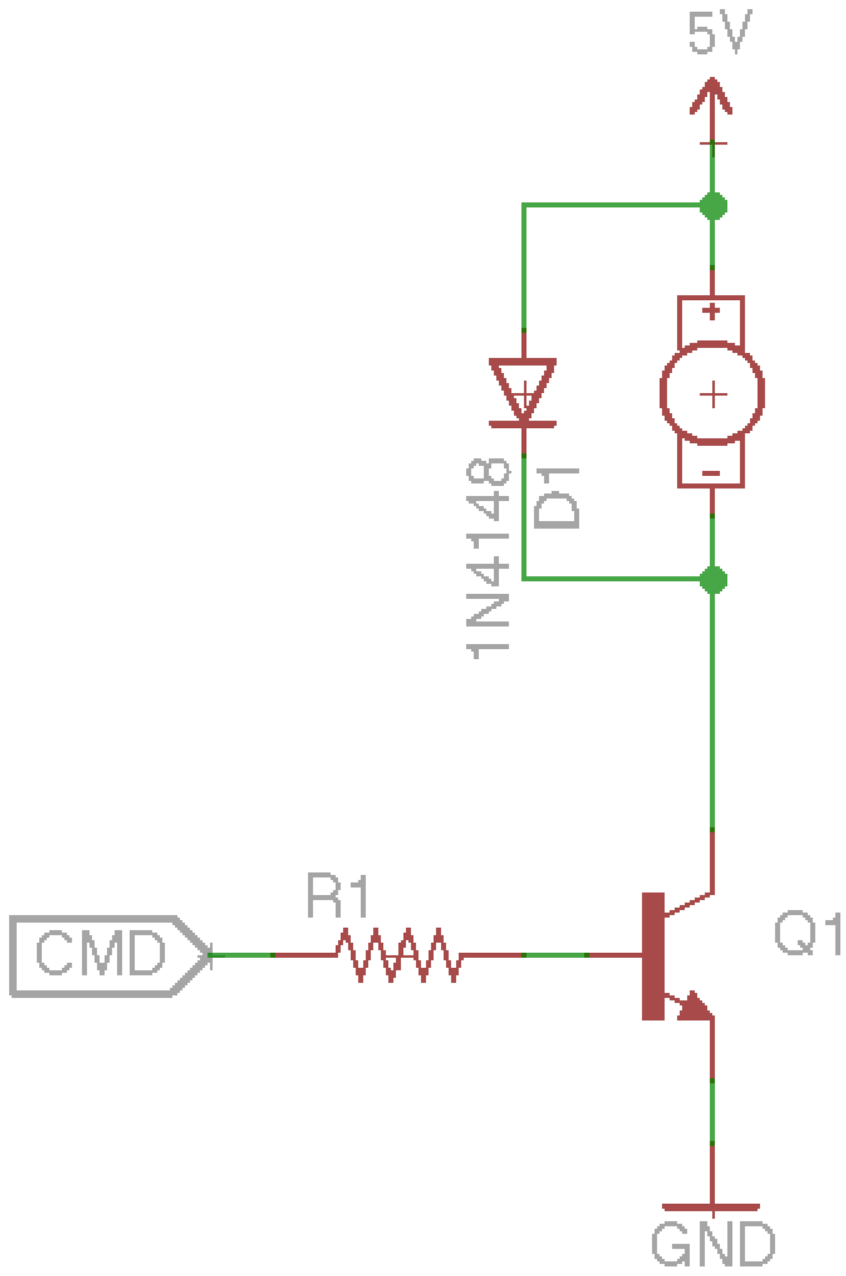
Porte H



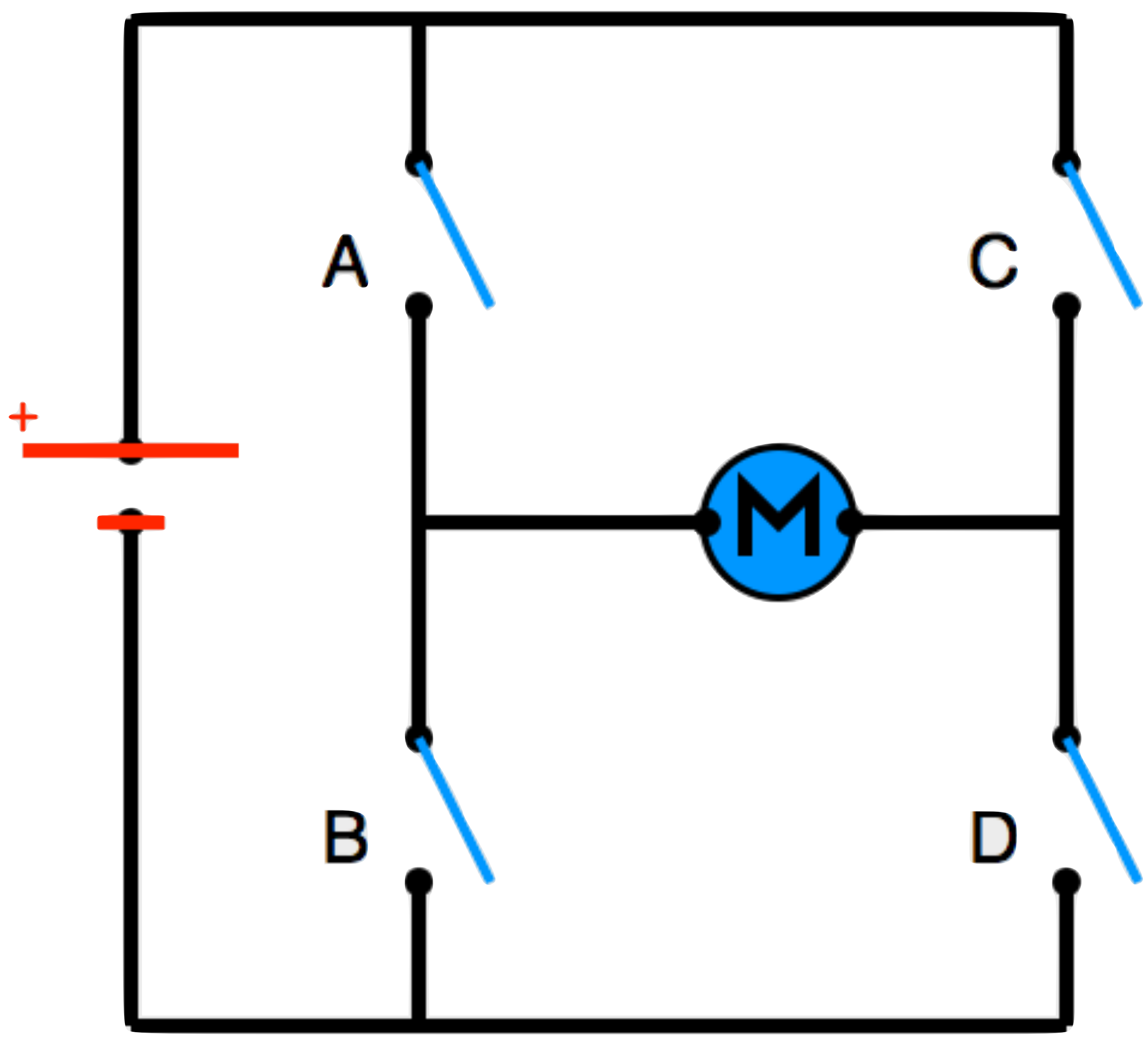
Commander un moteur

Simple

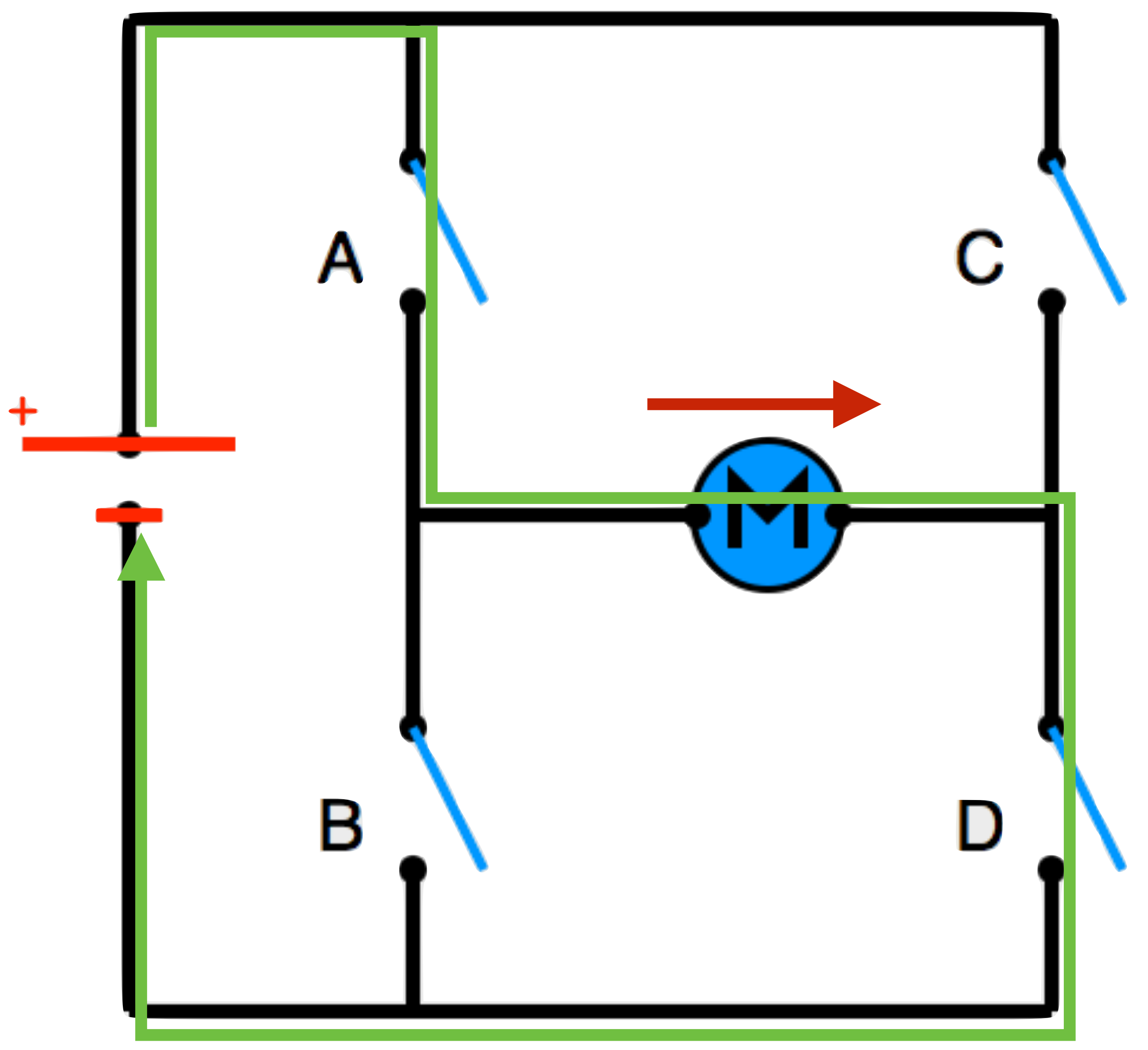
Un seul sens



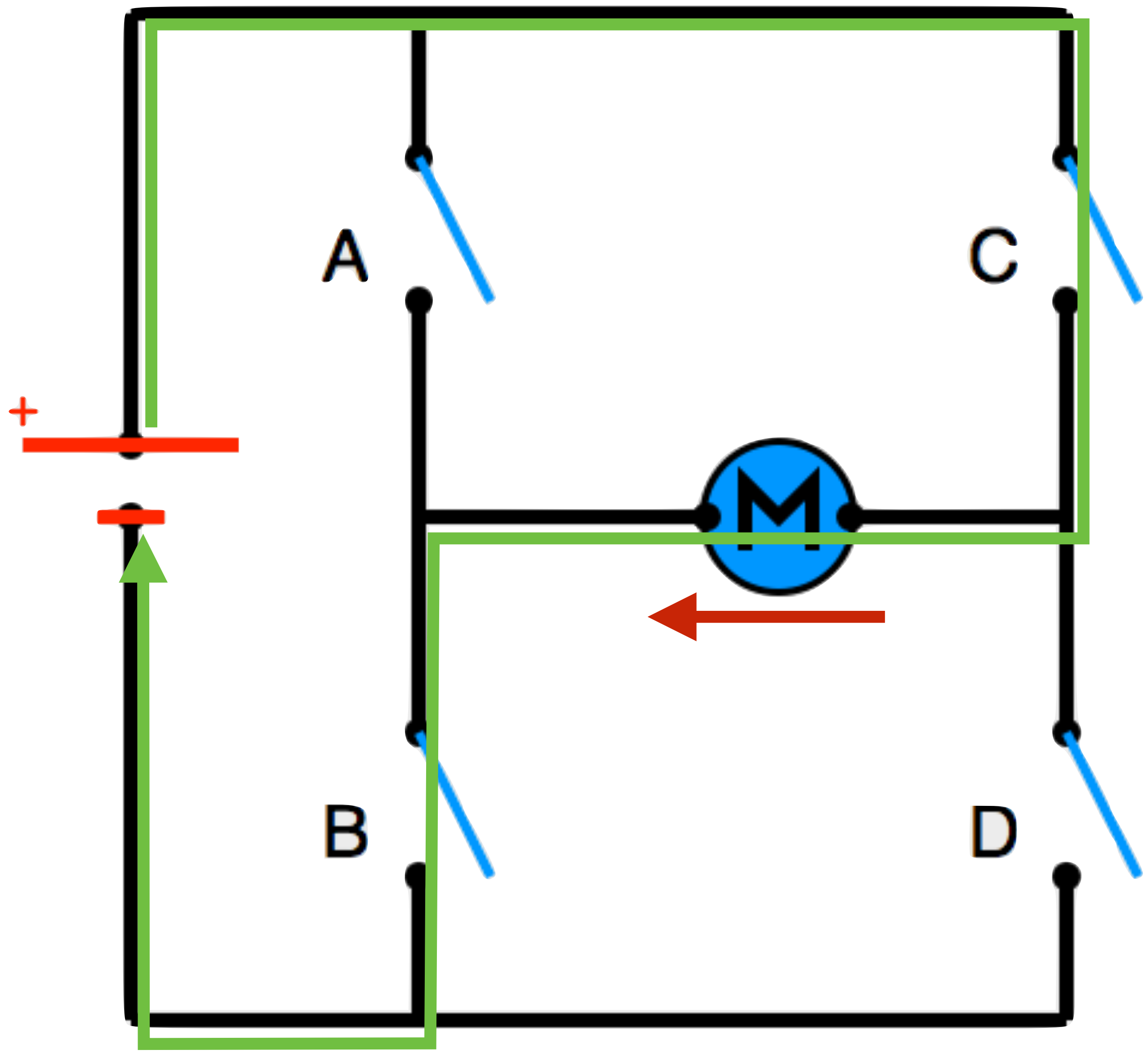
Porte en H



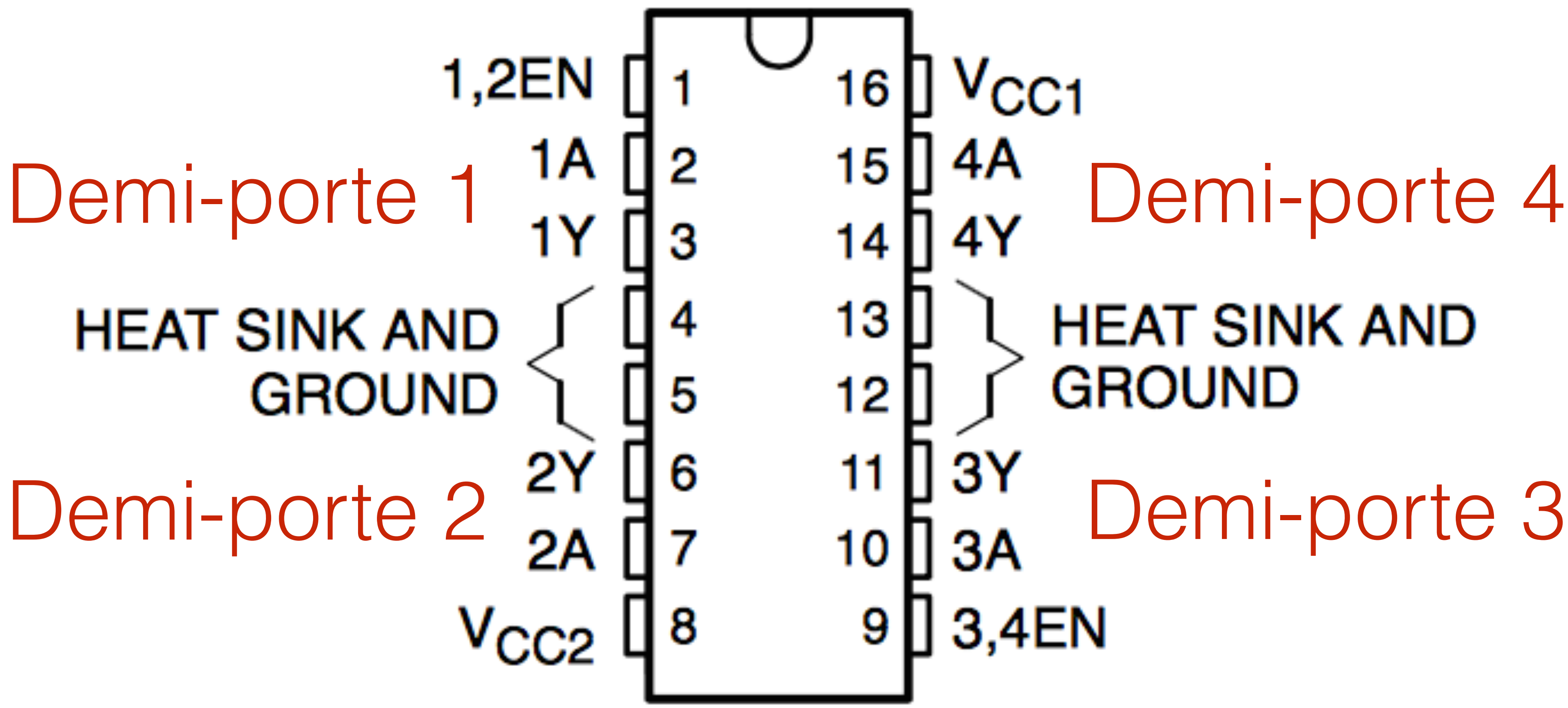
Porte en H



Porte en H



Porte en H



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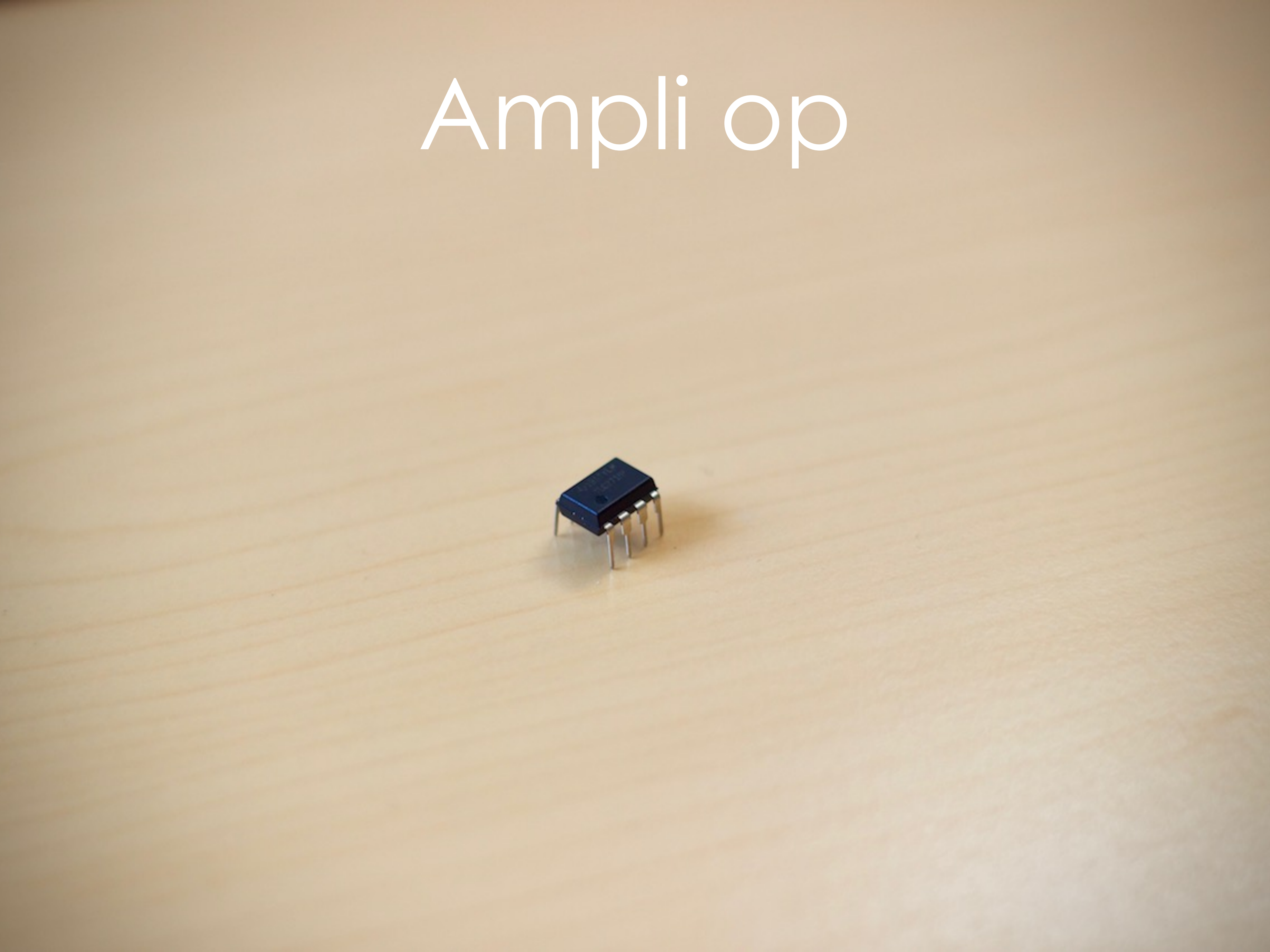
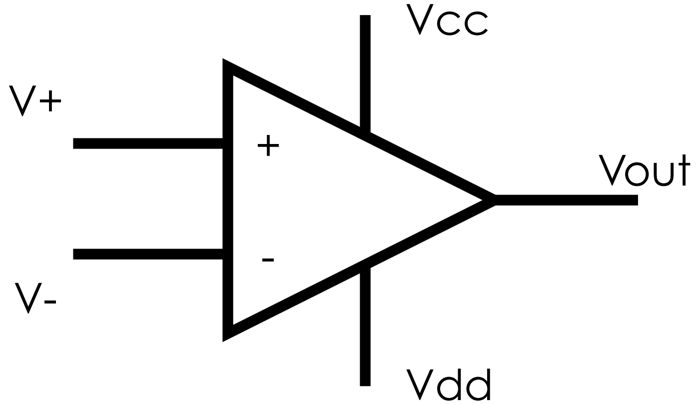

Ampli op

Ampli op



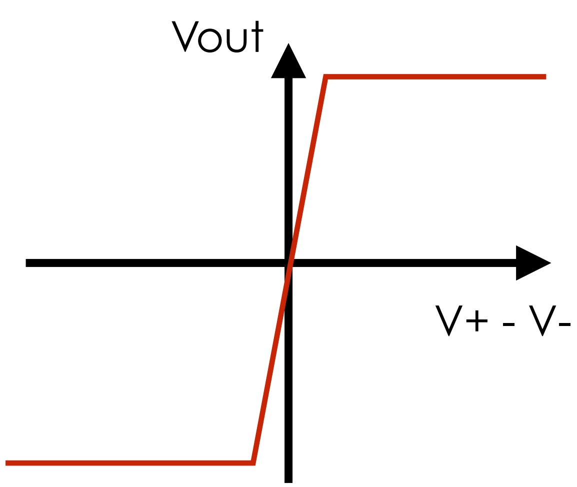
Couteau suisse de l'électronique

- Amplification
- Régulation de tension
- Comparateur
- ...

$$i_+ = i_- = 0$$

$$V_{out} = A(V_+ - V_-)$$

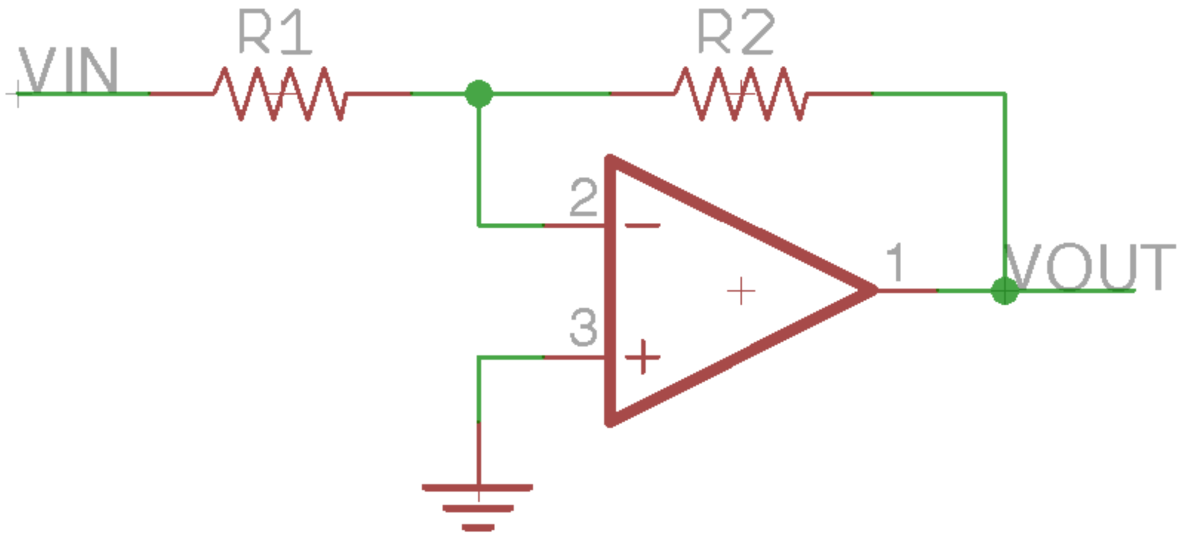
A très très grand



Ampli inverseur

Negative feedback

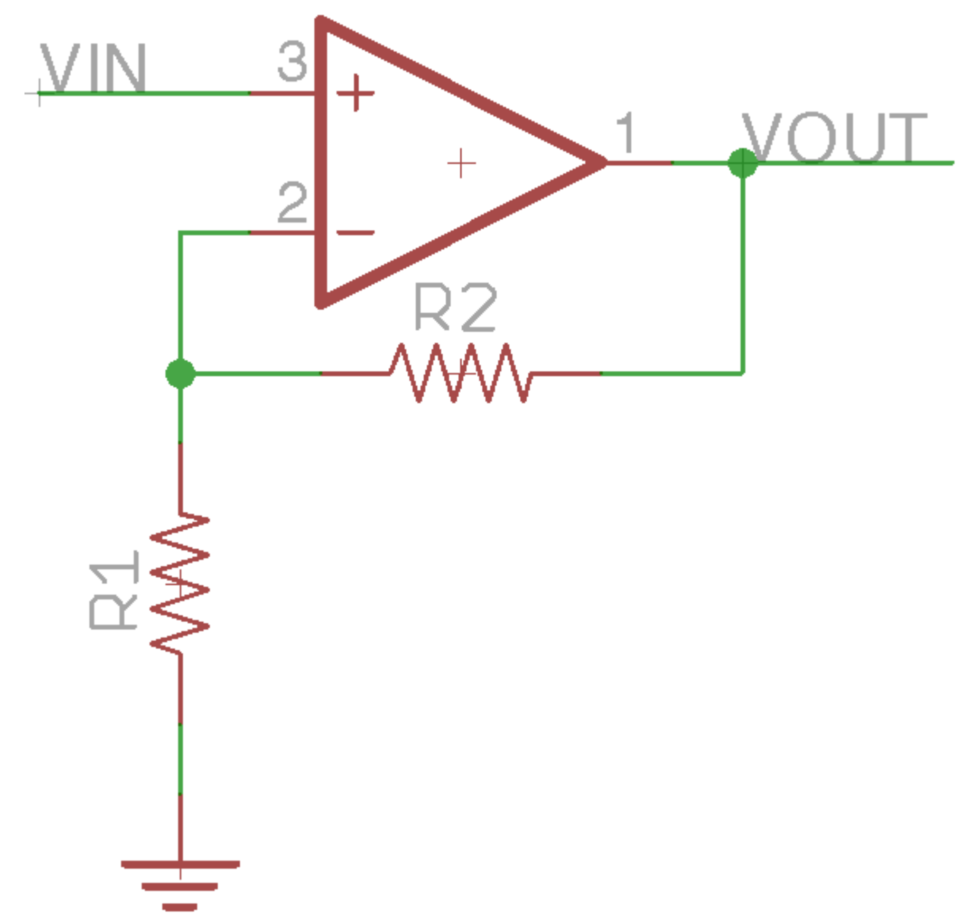
$$V_{out} = -V_{in}\frac{R_2}{R_1}$$



Ampli non inverseur

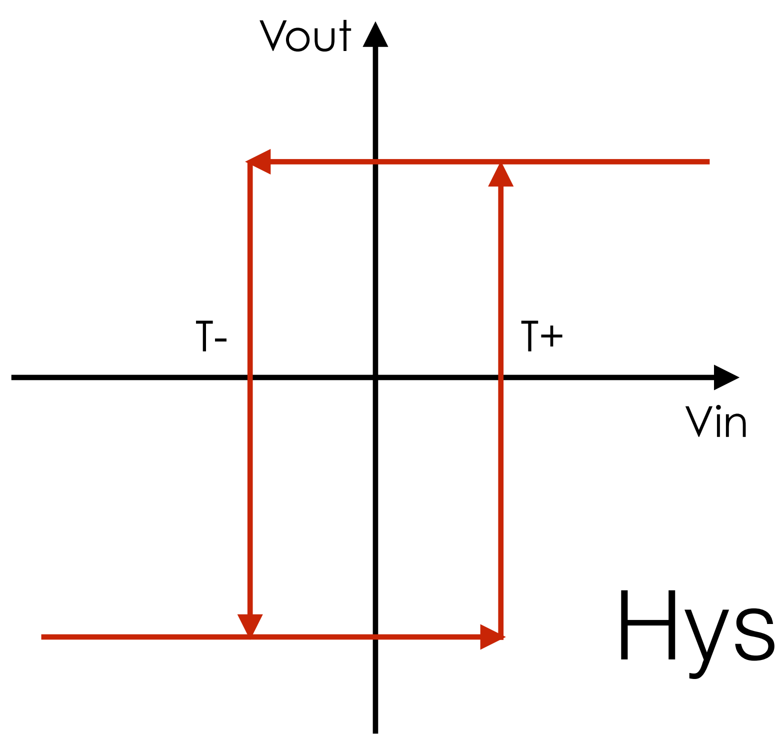
Negative feedback

$$V_{out} = V_{in} \frac{R_1 + R_2}{R_1}$$

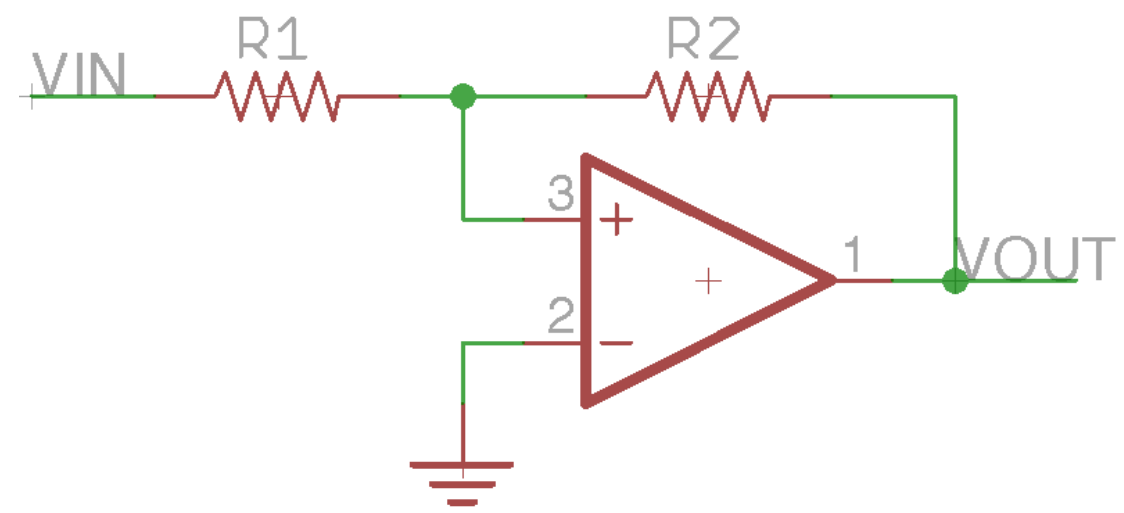


Trigger de Schmitt

$$V_{T+} = V_{cc}\frac{R_1}{R_2}$$
$$V_{T-} = -V_{cc}\frac{R_1}{R_2}$$

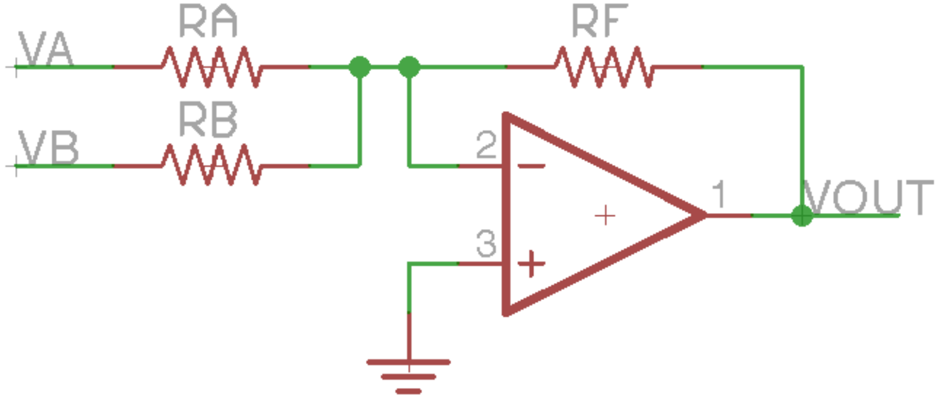


Hystérésis



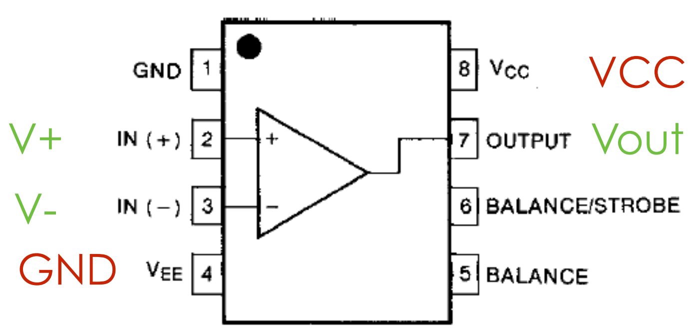
Trigger de Schmitt

$$V_{out} = -(\frac{R_f}{R_a}V_a + \frac{R_f}{R_b}V_b)$$

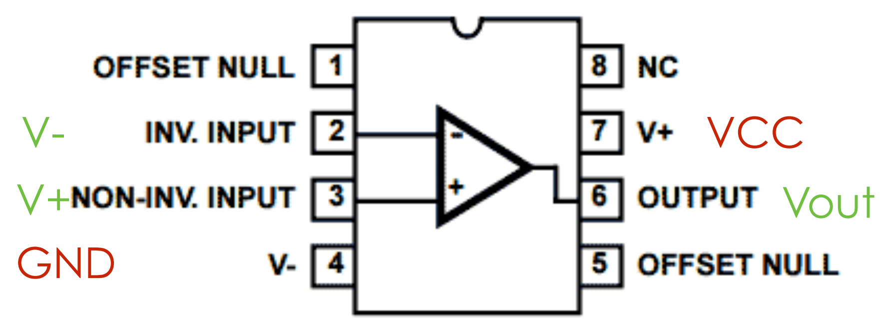


Ampli op

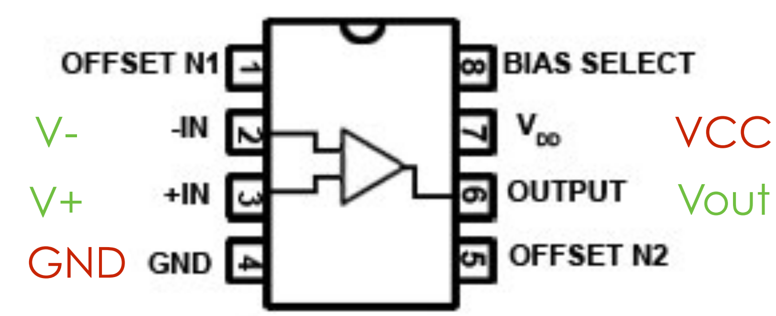
LM311



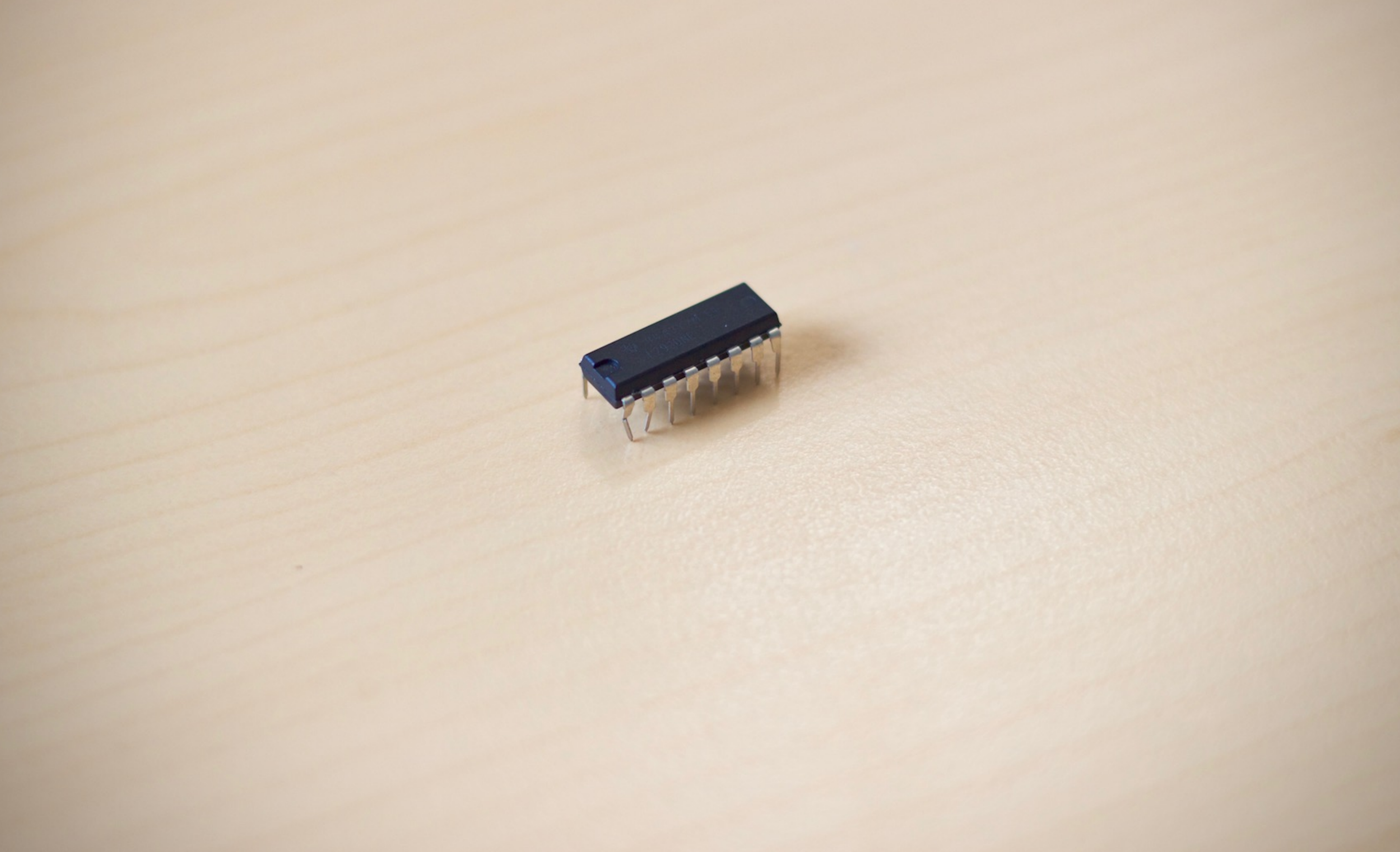
LM741



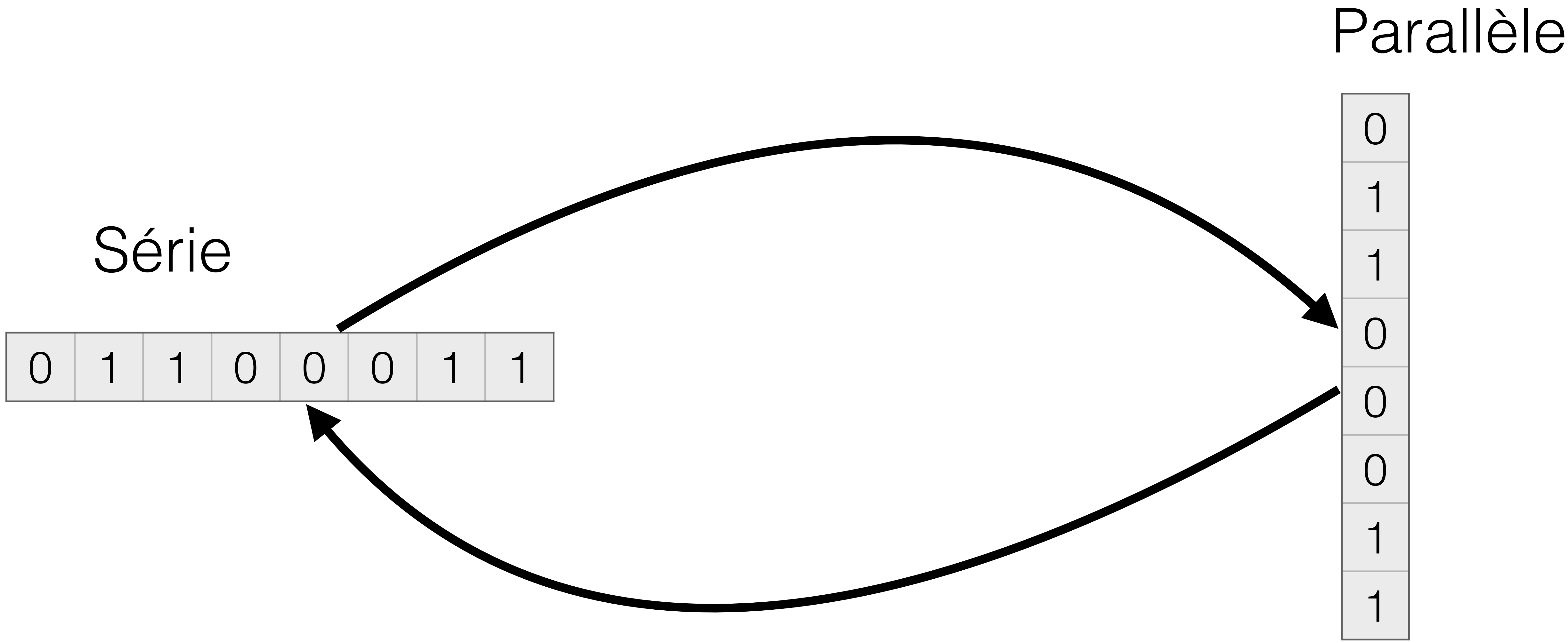
TLC271



Registre à décalage

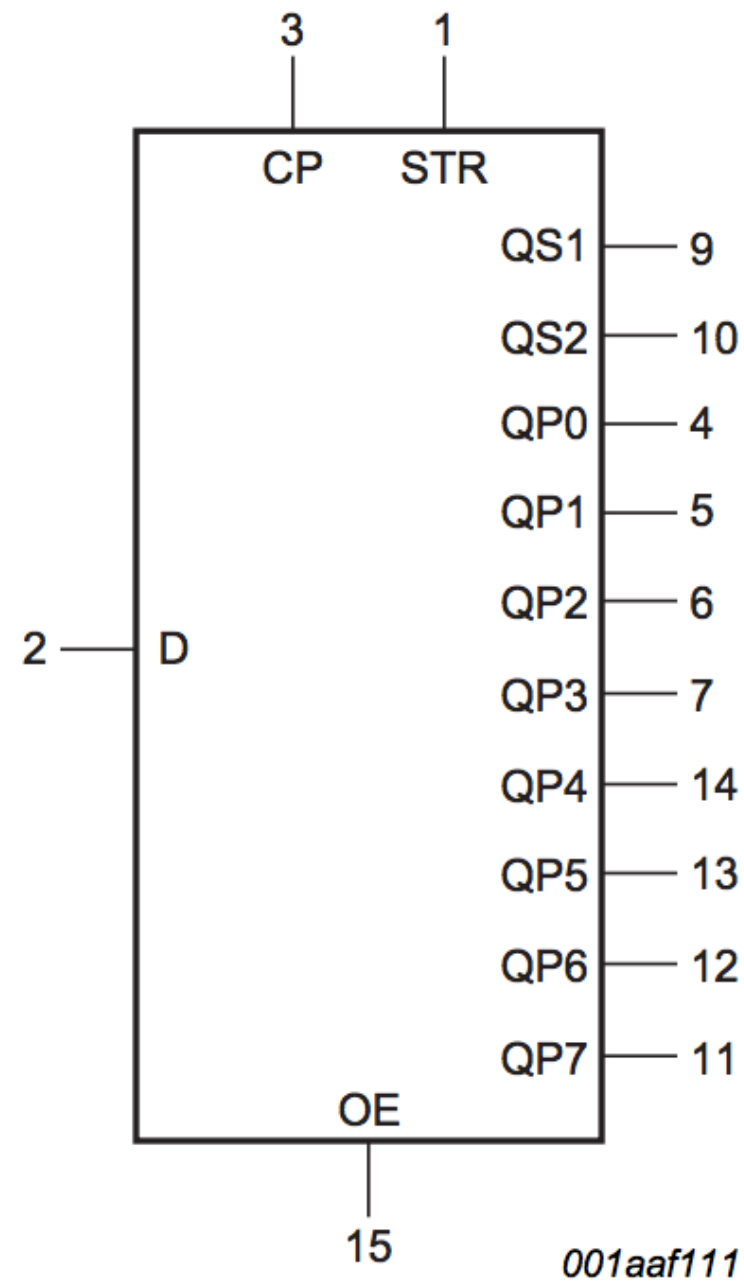


Série / parallèle



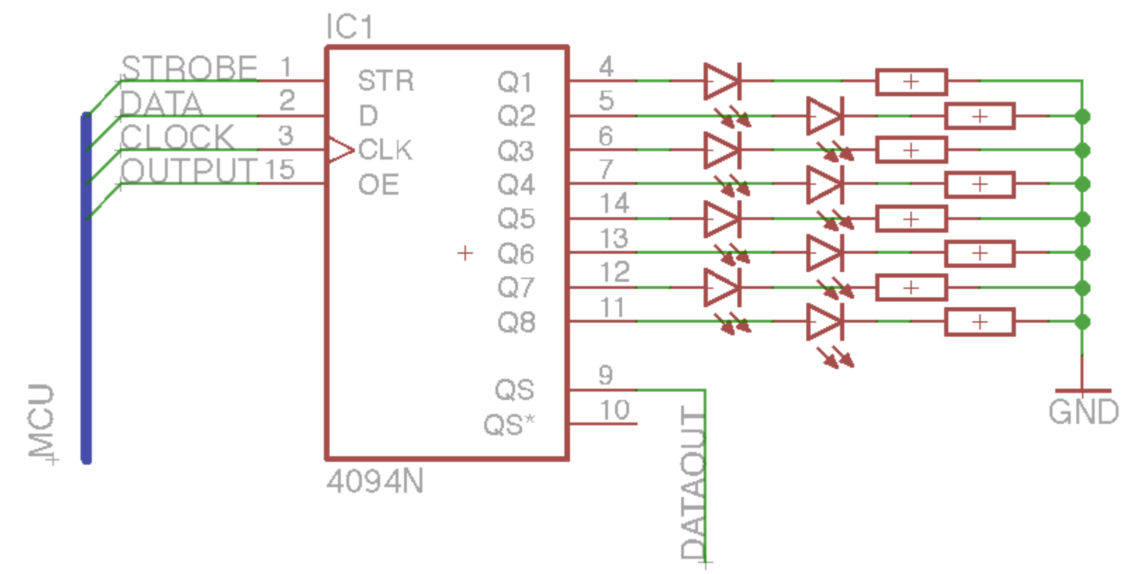
Registre à décalage

- CP : horloge
- D : données (en série)
- STR : enregistrement dans un registre
- OE : valeur du registre aux sorties parallèles
- QP0 - QP7 : sorties parallèles
- QS1, QS2 : sorties série
- + / - : alimentation



Registre à décalage

- Strobe, data, clock, output : du MCU
  - Data : MOSI (SPI)
- $Q_1 \Rightarrow Q_8$: sorties
- Q_S : ajouter des sorties
  - Remplacer data par Qs
  - Ajouter Strobe clock et output



Multiplexeur

8 entrées pour contrôler 16 sorties

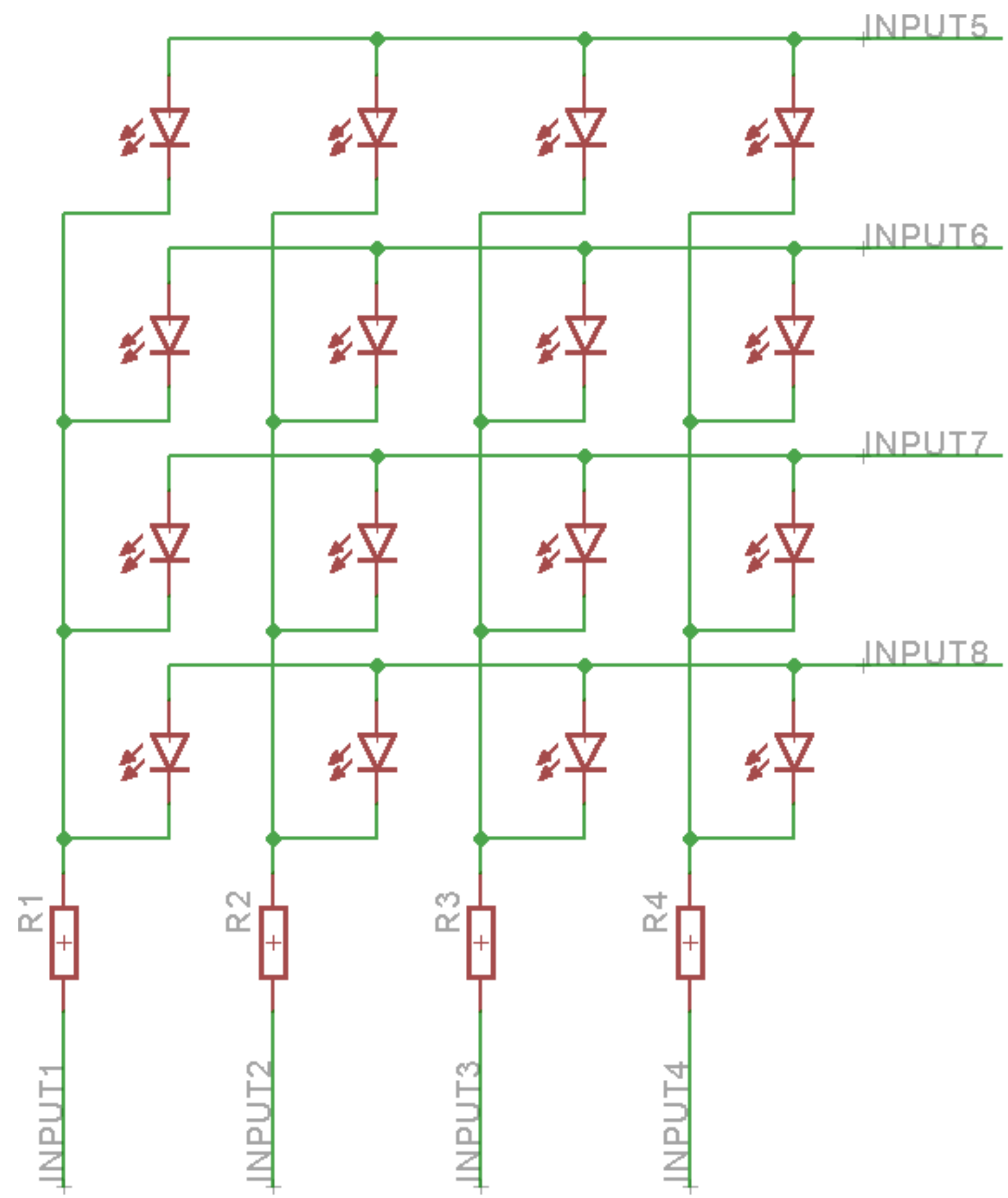
- Registres à décalage

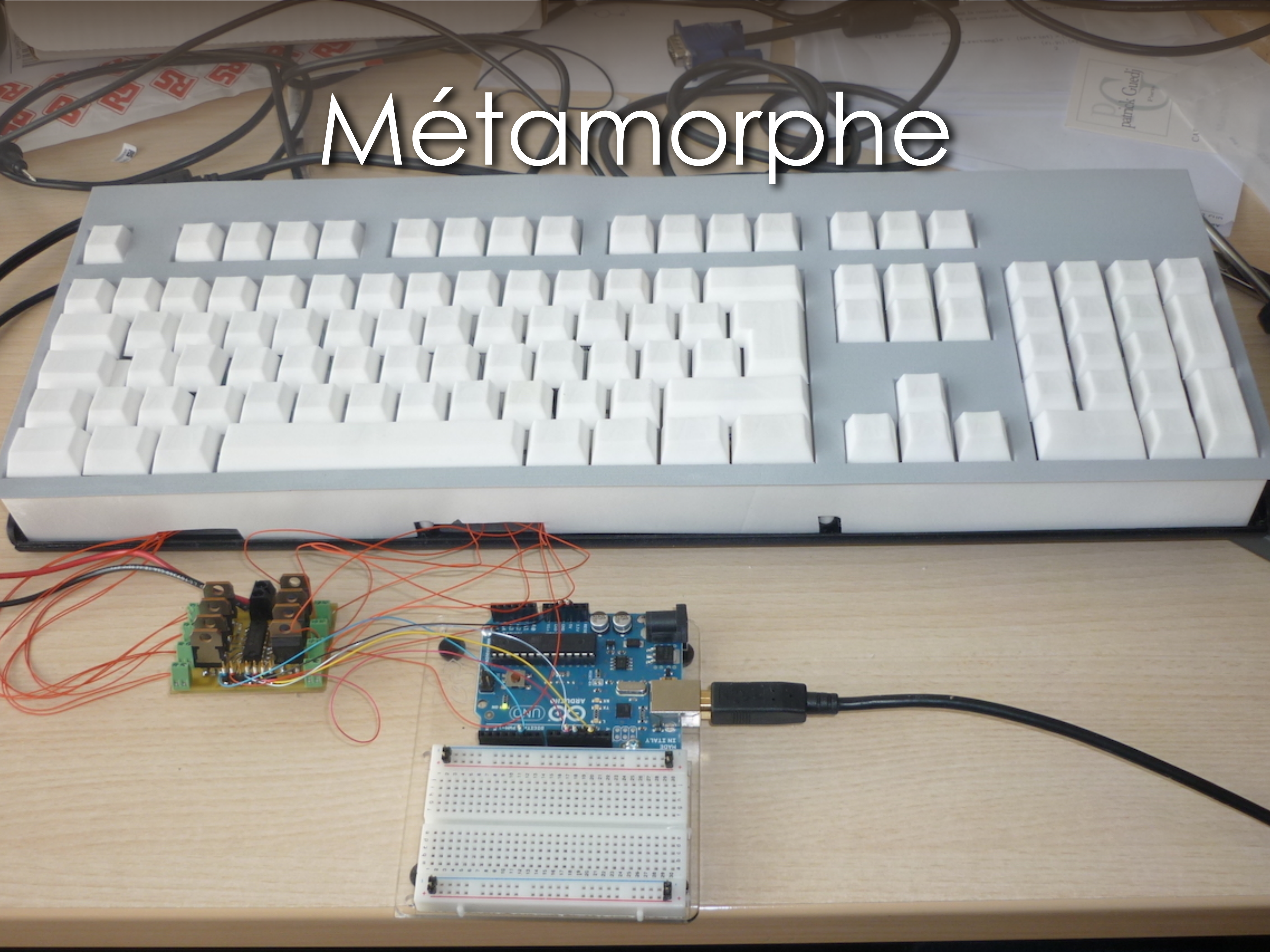
Choix de la led :

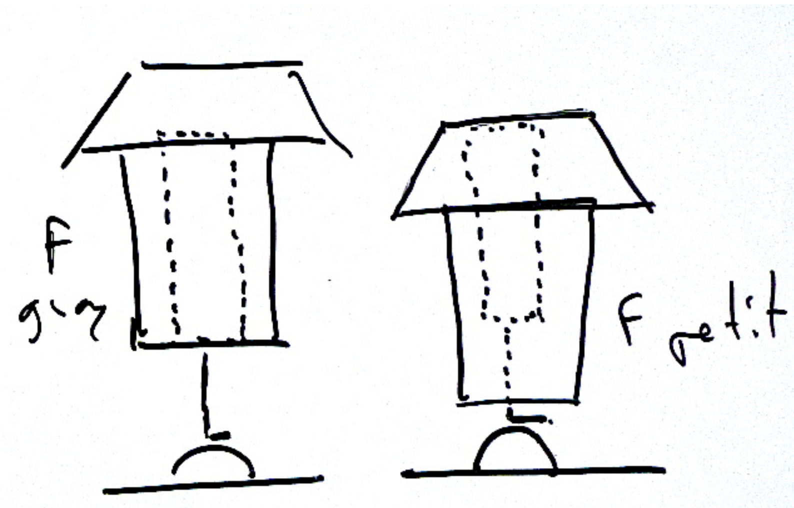
- Ligne HIGH, colonne LOW
- Autres lignes LOW, autres colonnes HIGH

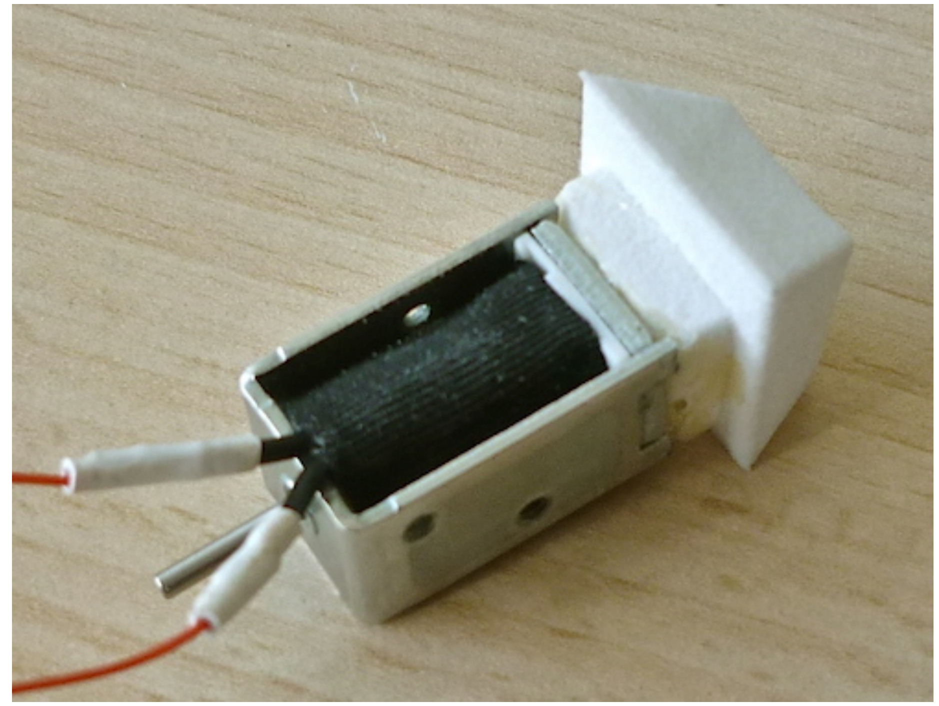
Plusieurs LEDs

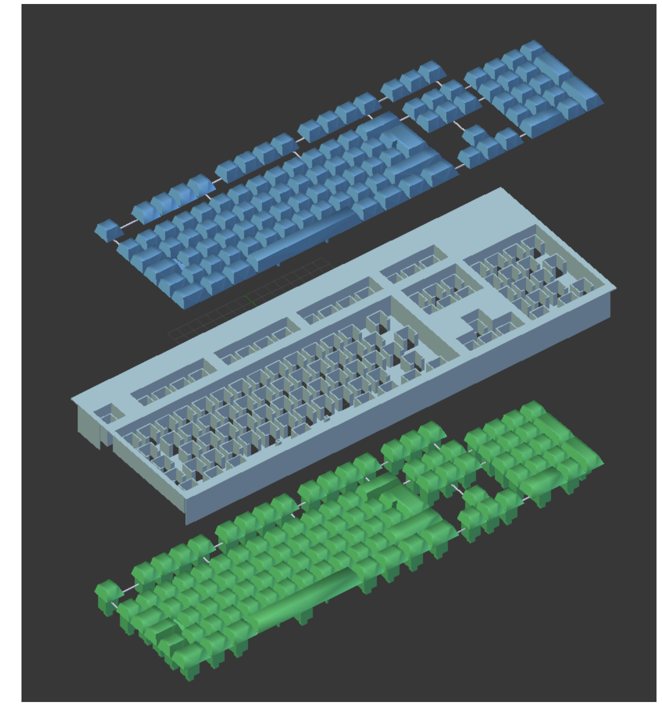
- Persistance rétinienne




Métamorphe

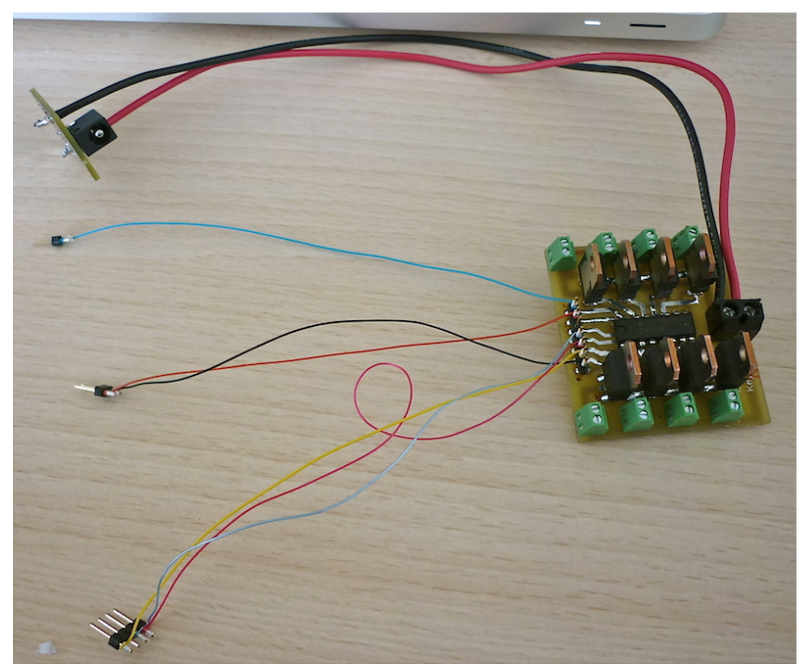

F petit

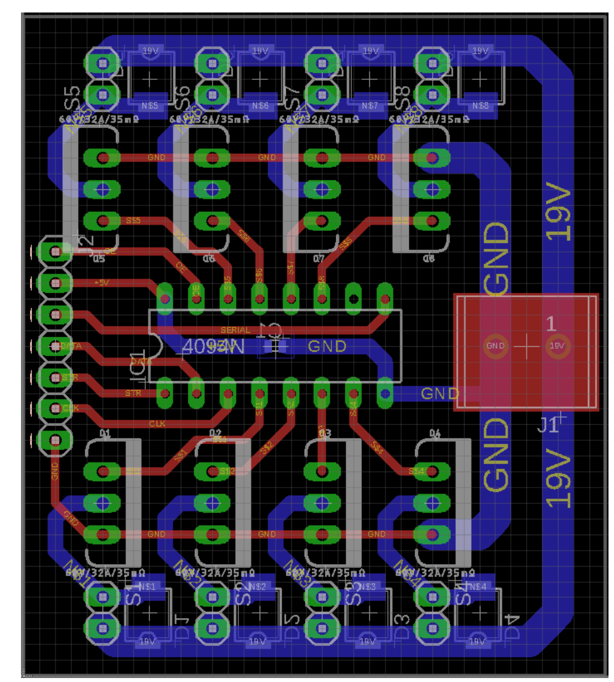


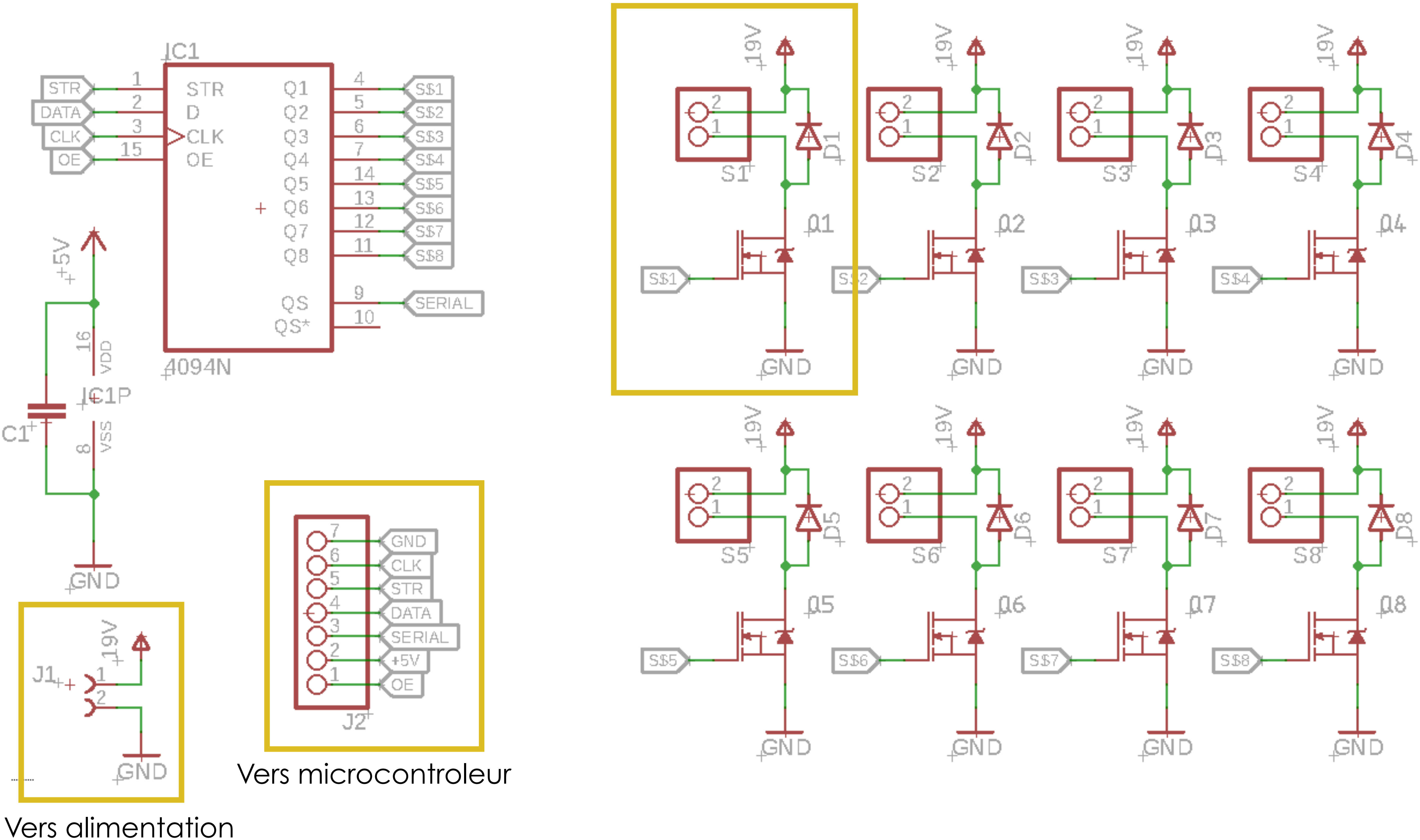


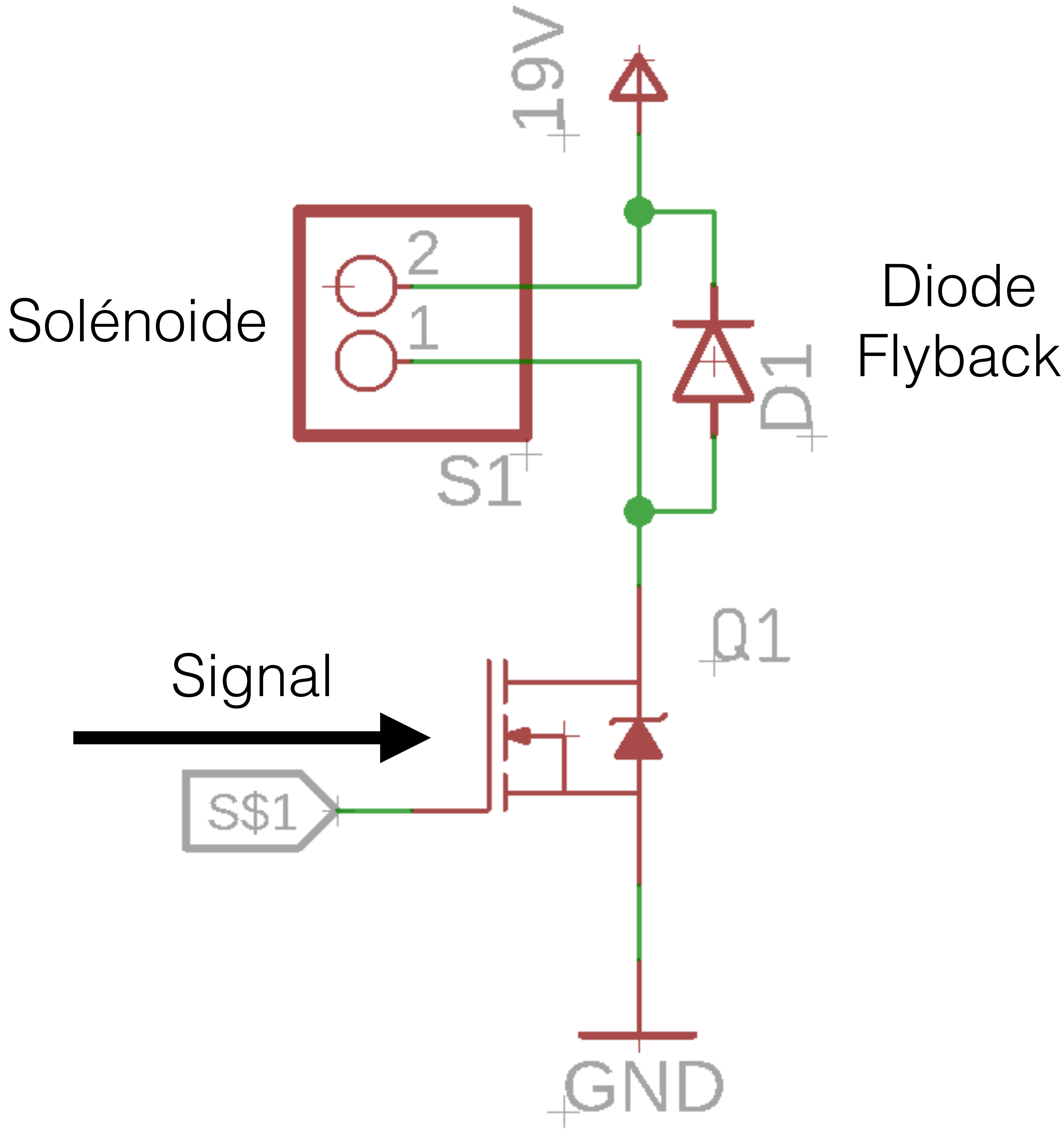

10/08
300532217


10/08
300532217

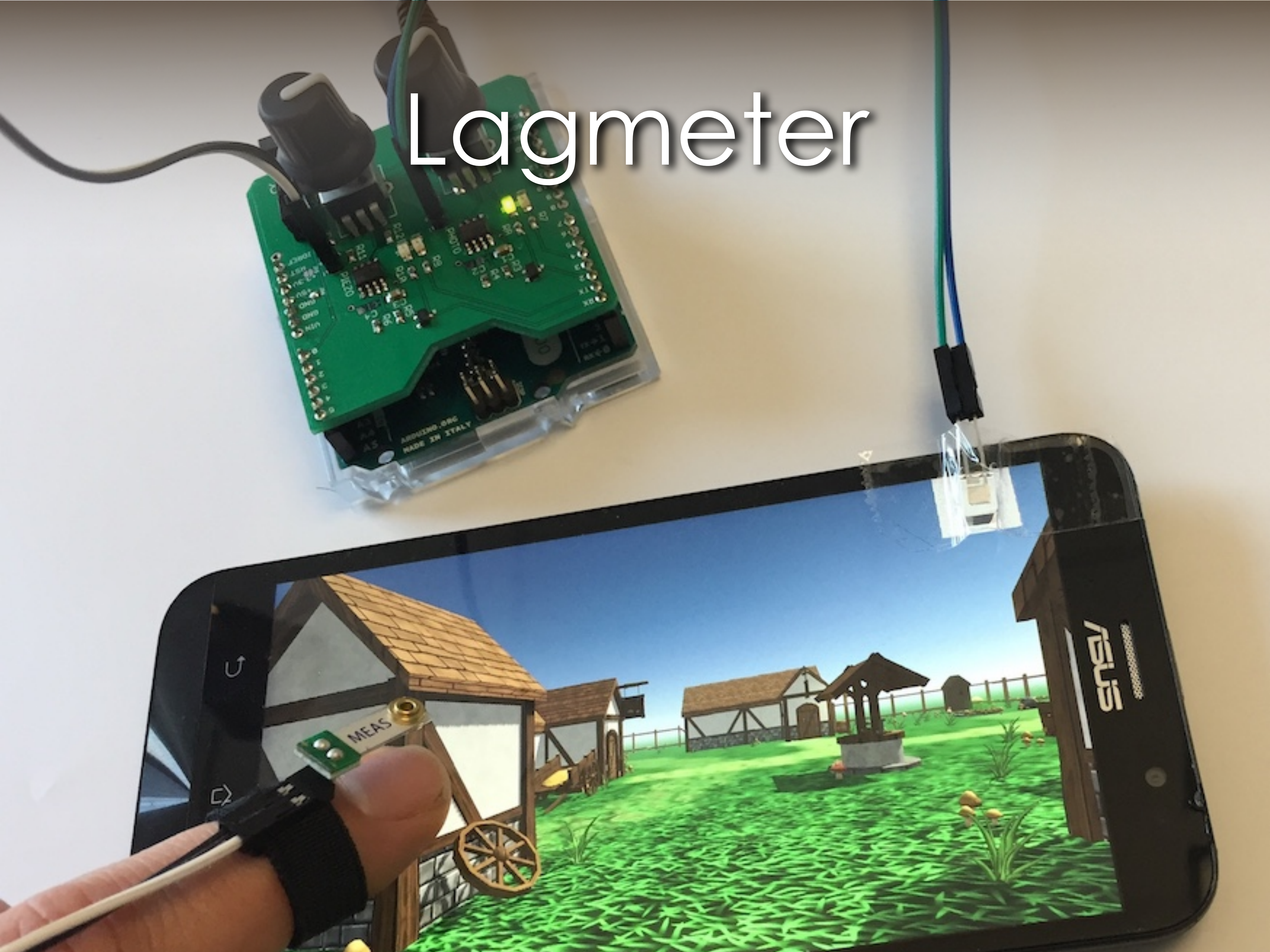


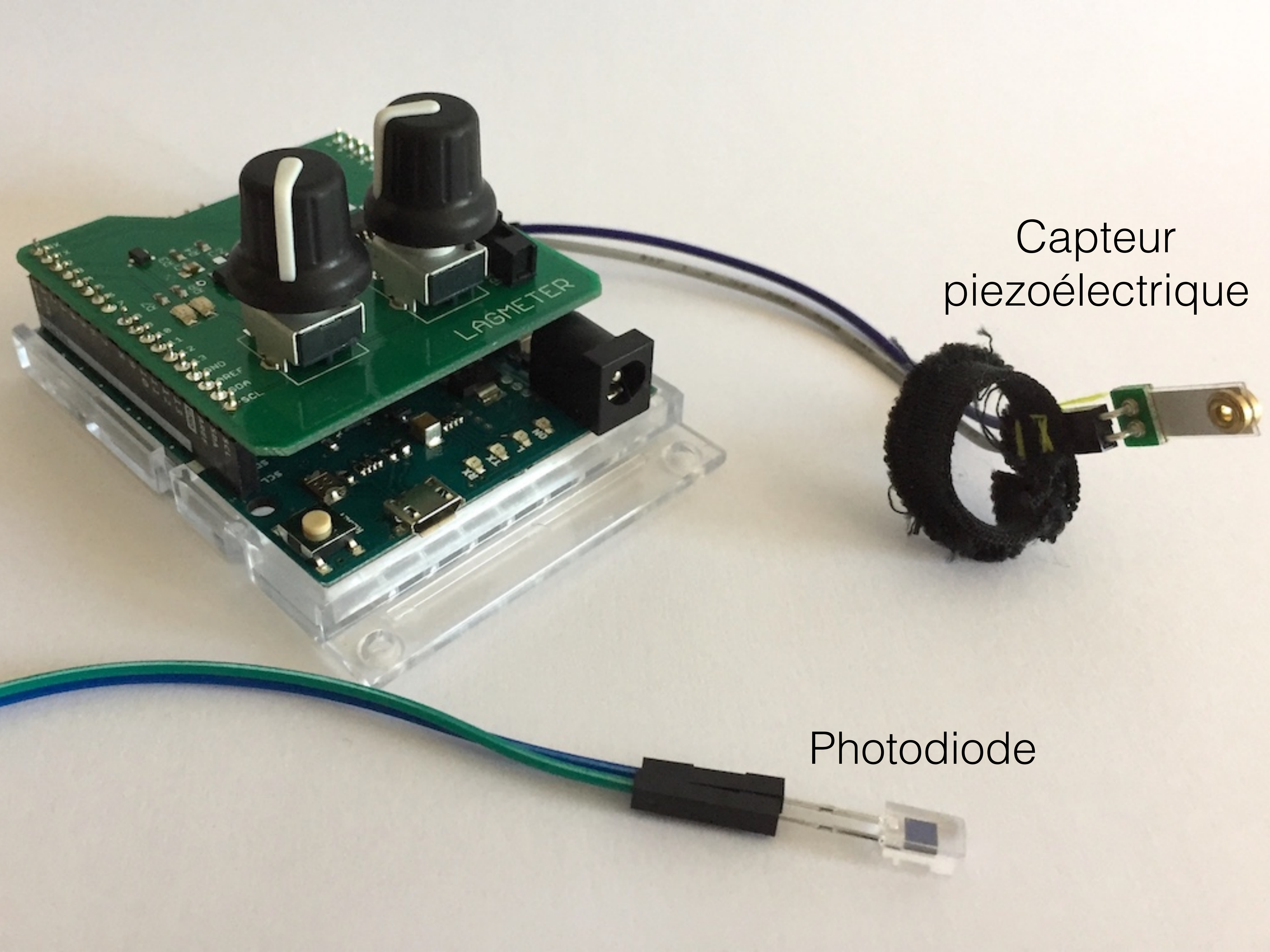

4094N
GND
19V
GND
19V
J1


IC1
STR
D
CLK
OE
Q1
Q2
Q3
Q4
Q5
Q6
Q7
Q8
QS
QS*
4094N
STR
DATA
CLK
OE
S$1
S$2
S$3
S$4
S$5
S$6
S$7
S$8
SERIAL
+5V
VDD
IC1P
VSS
C1
GND
19V
J1
J2
GND
CLK
STR
DATA
SERIAL
+5V
OE
S1
S2
S3
S4
S5
S6
S7
S8
D1
D2
D3
D4
D5
D6
D7
D8
Q1
Q2
Q3
Q4
Q5
Q6
Q7
Q8
Vers microcontroleur
Vers alimentation

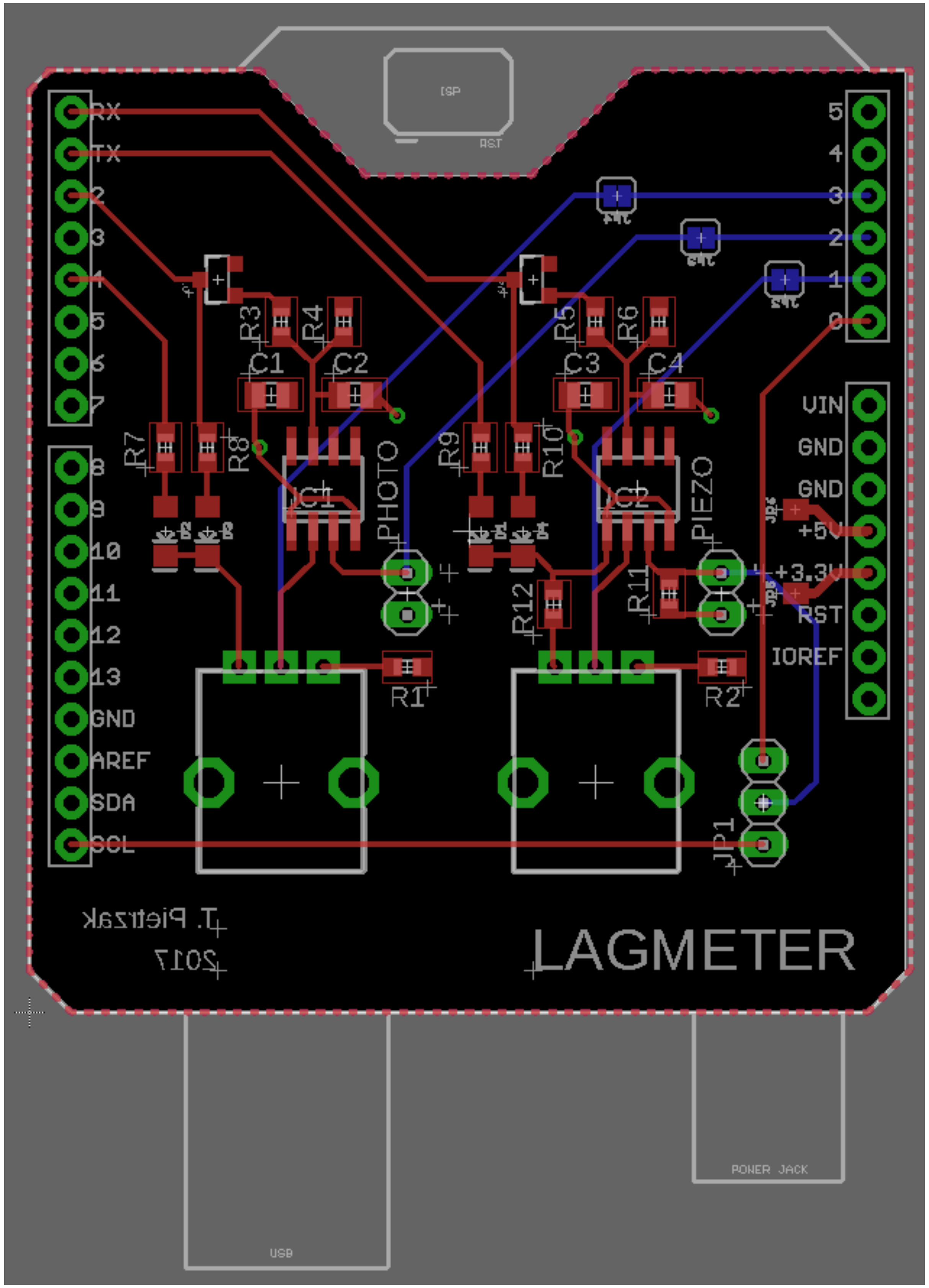

19V
Solénoide
2
1
S1
Diode
Flyback
D1
Q1
Signal
S$1
GND

Lagmeter

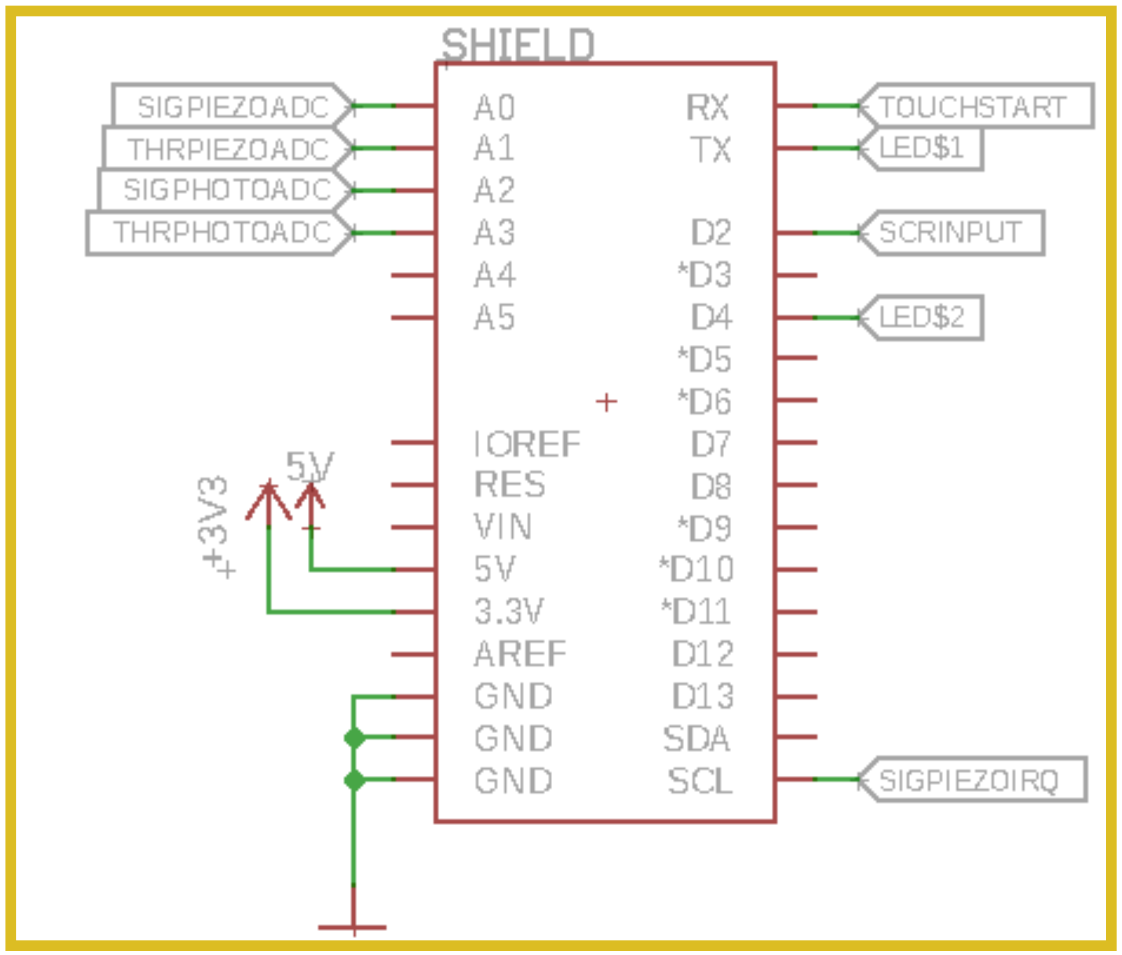


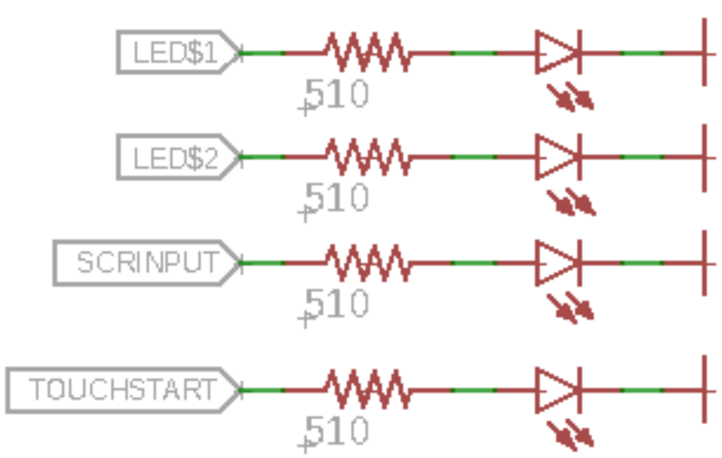

LAGMETER
Capteur
piezoélectrique
Photodiode


ARDUINO
LEONARDO
DIGITAL (PWM~)
RESET

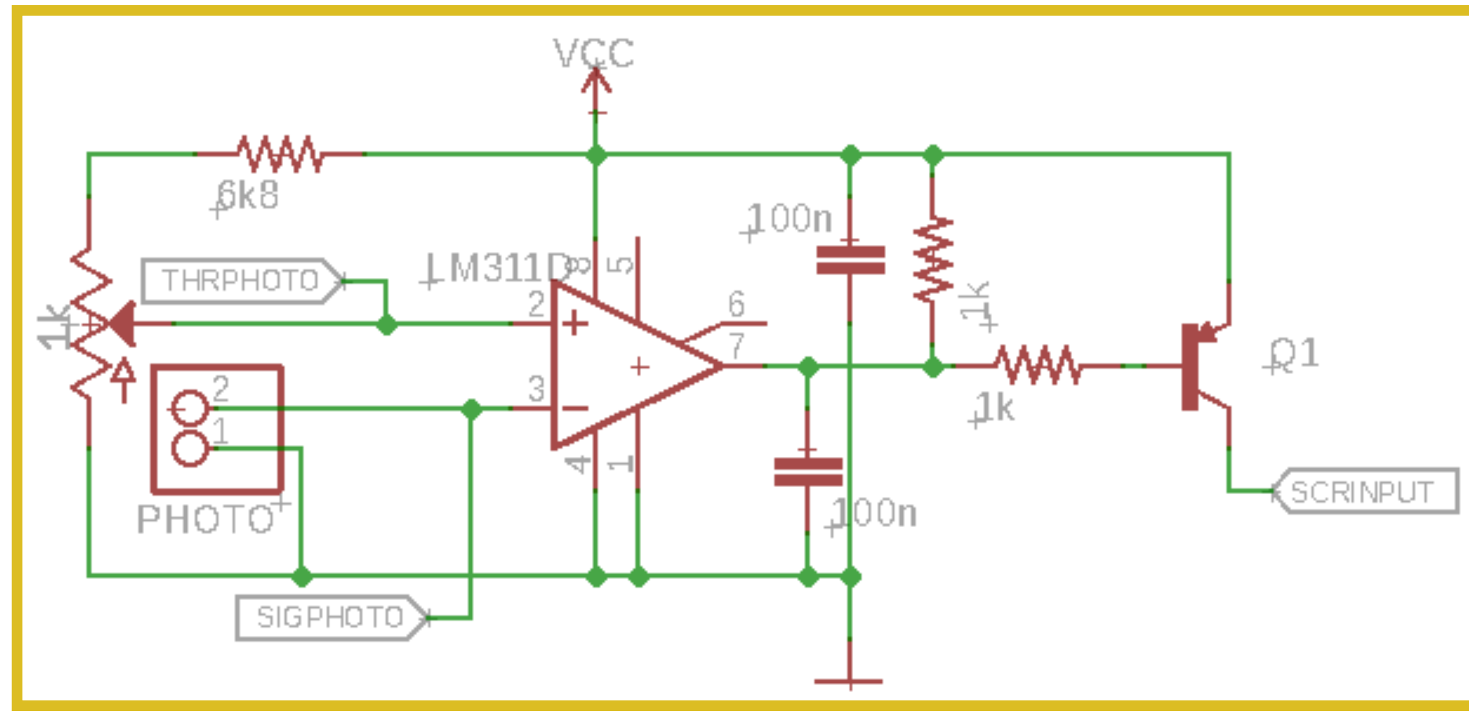

ISP
RX
TX
GND
AREF
SDA
SCL
VIN
+5V
+3.3V
RST
IOREF
R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
C1
C2
C3
C4
IC1
IC2
PHOTO
PIEZO
JP1
T. Pietrzak
2017
LAGMETER
USB
POWER JACK

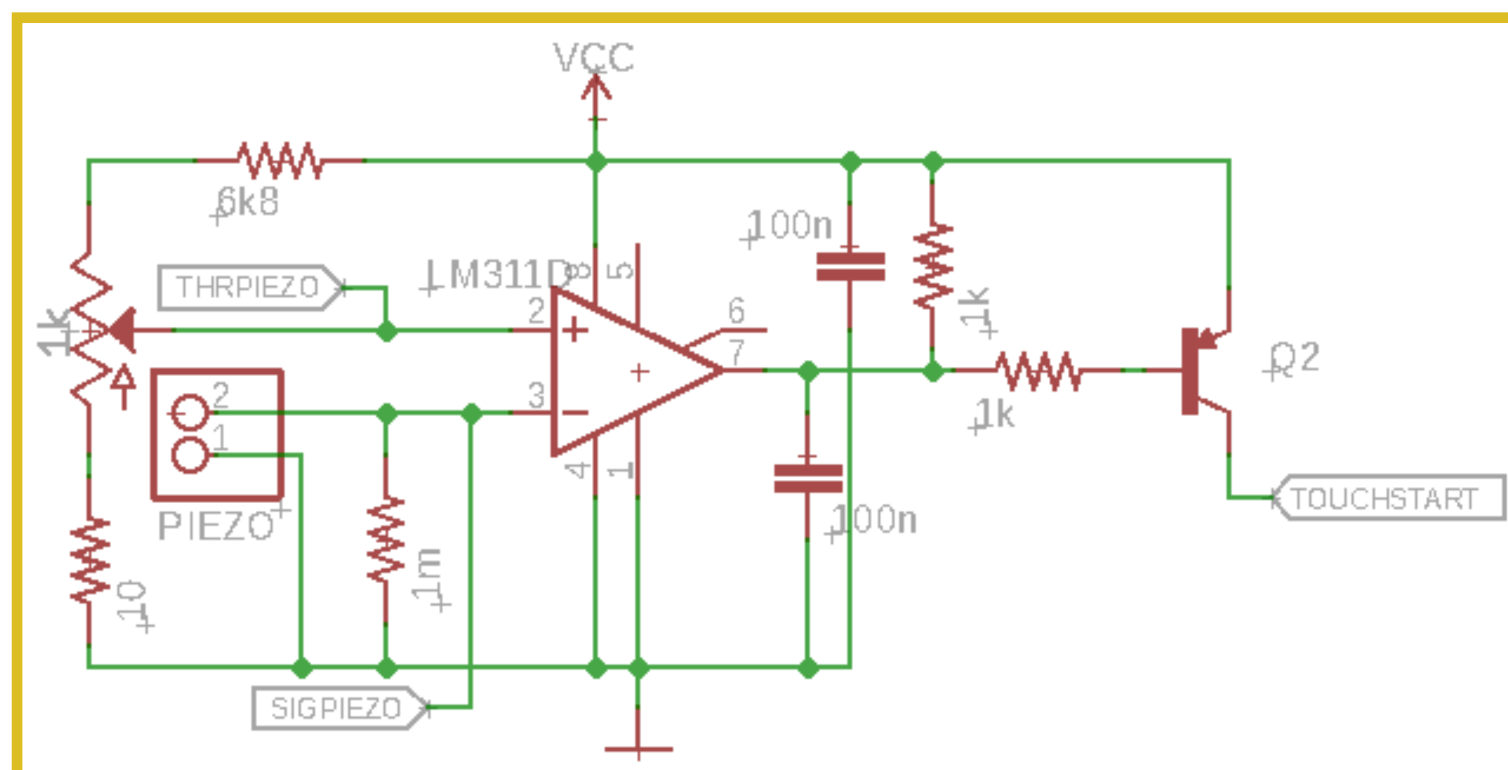
Pins shield



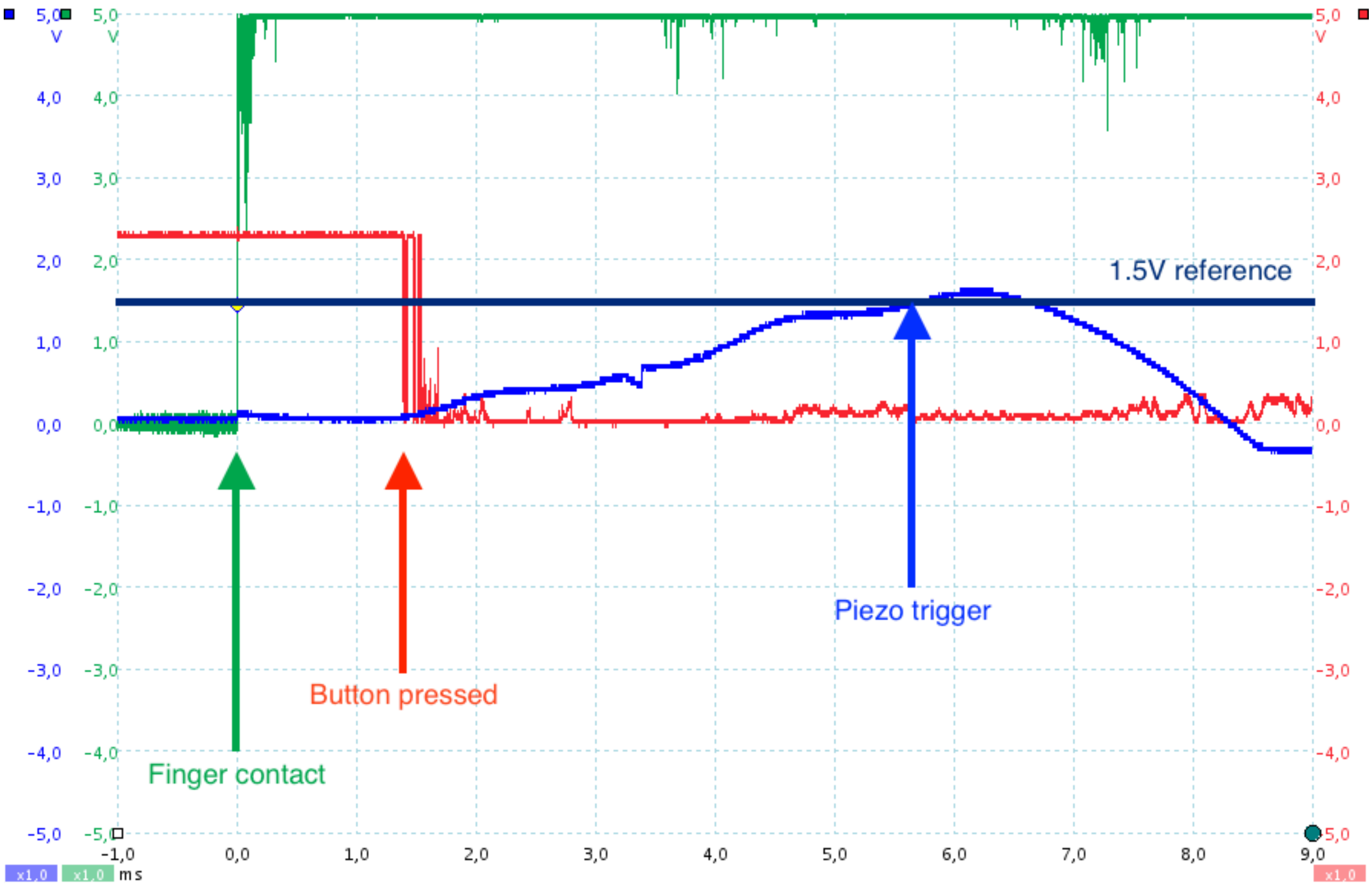


Détection de lumière

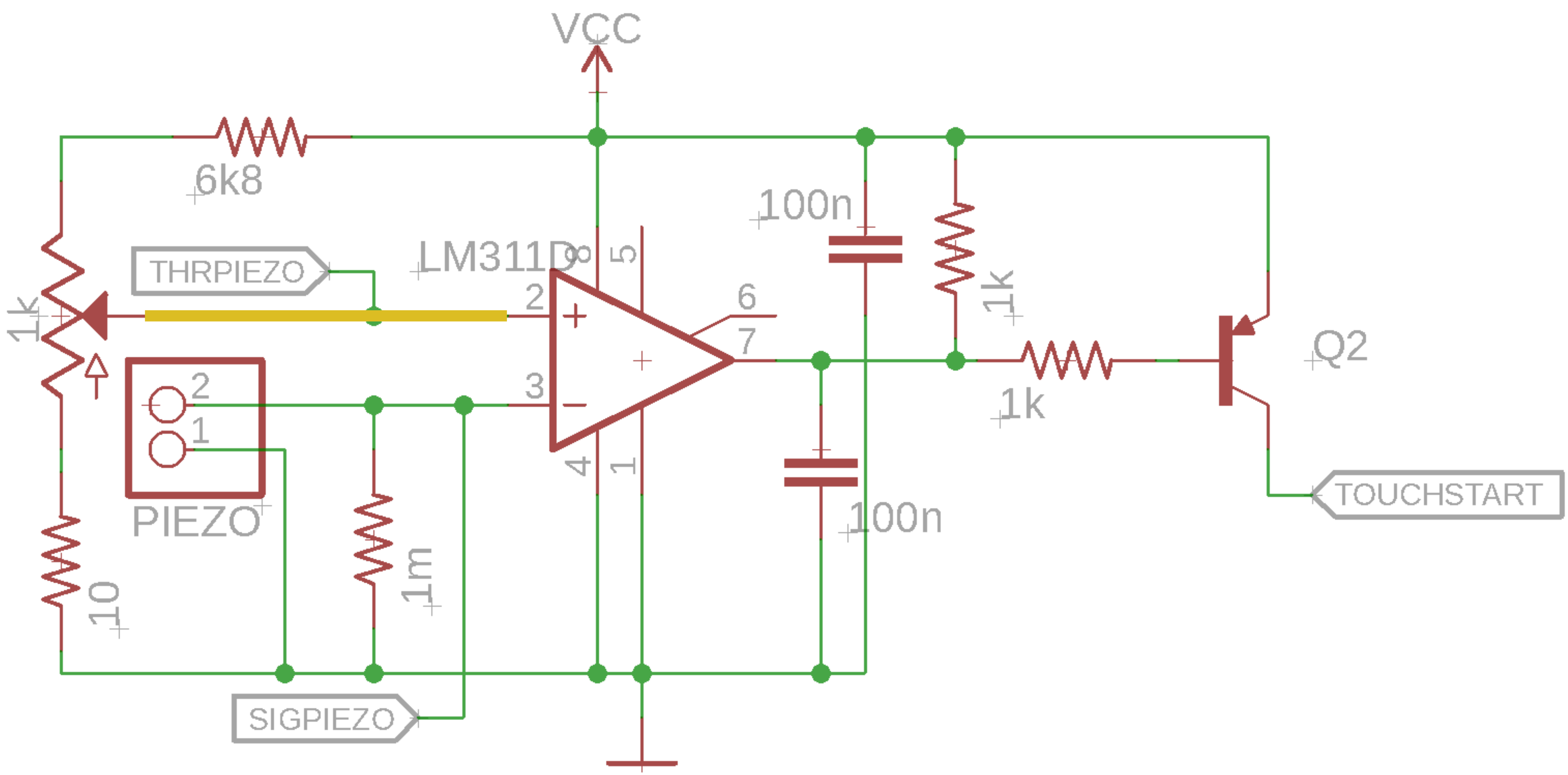




Détection de vibration

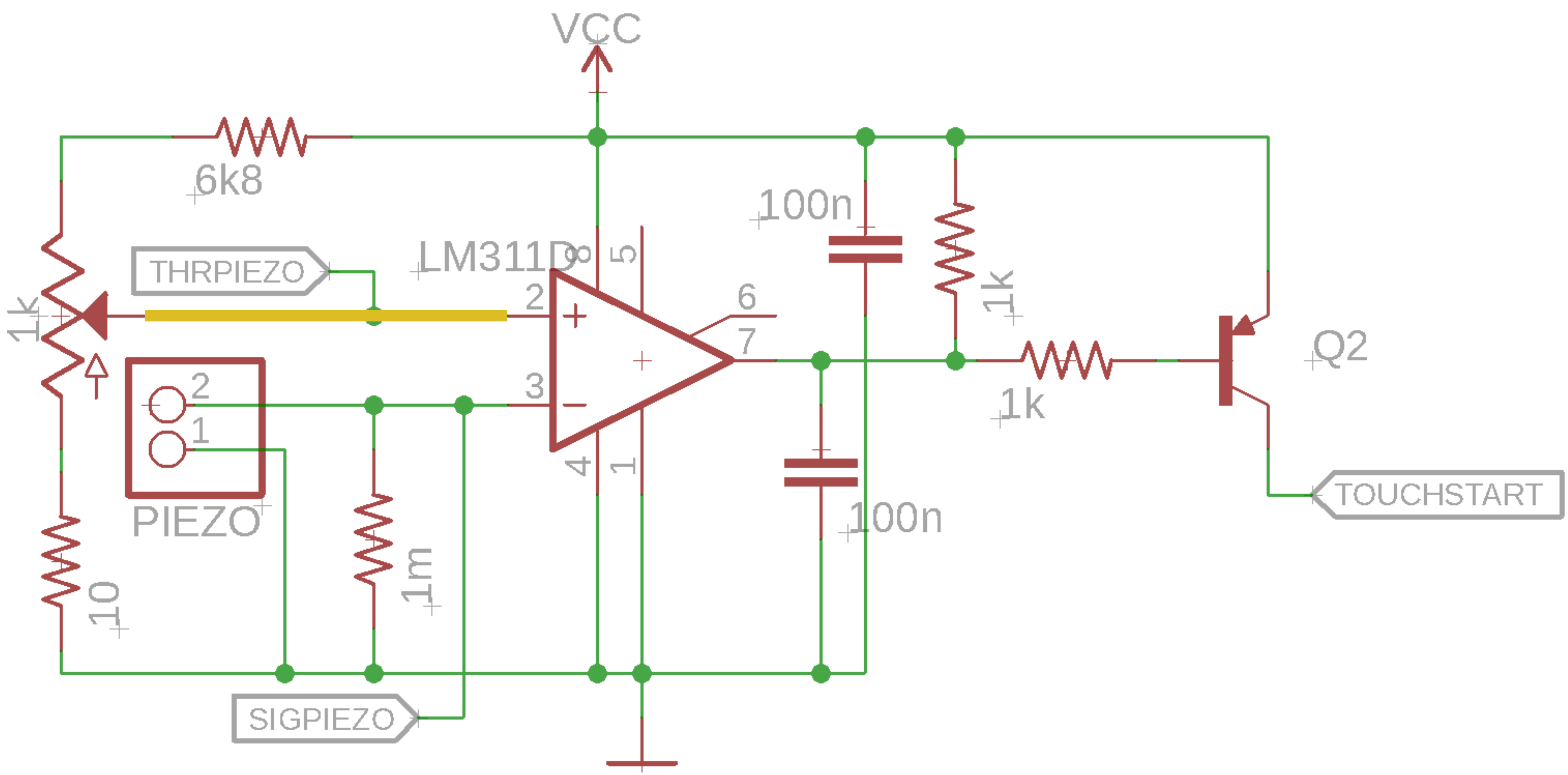


1.5V reference
Piezo trigger
Button pressed
Finger contact
ms



Vcc = 5V

THRPIEZO = ?



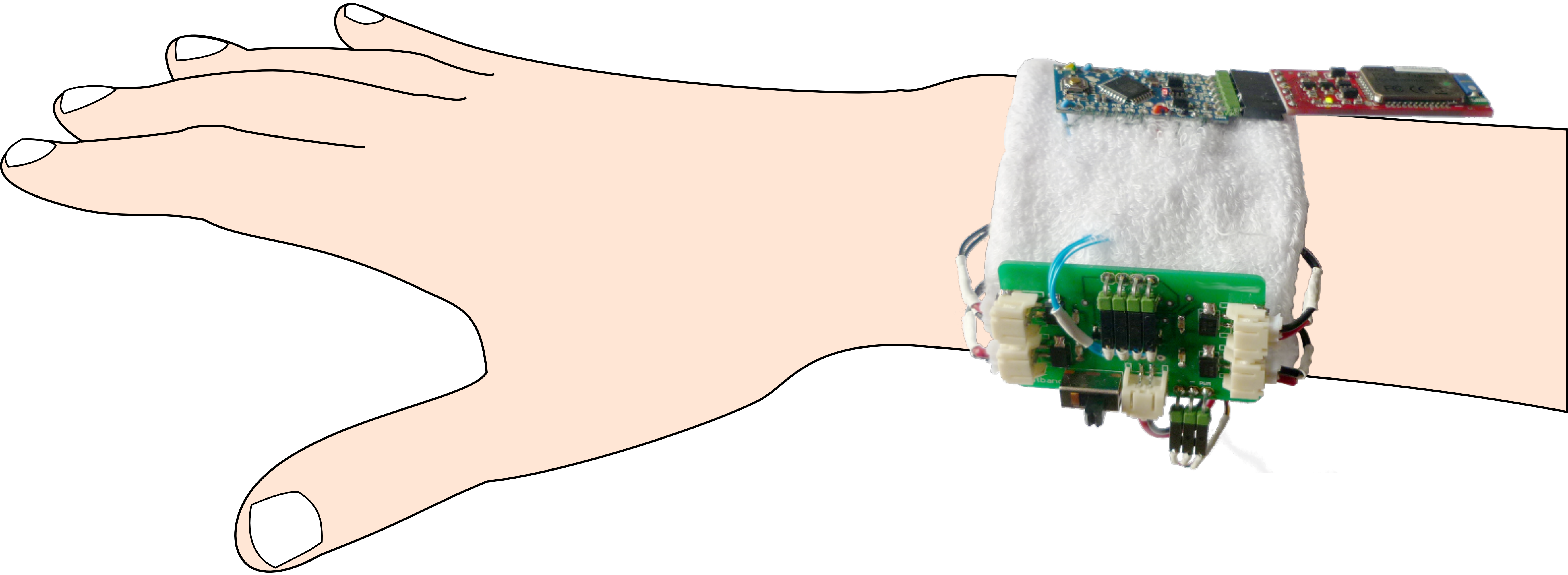
Vcc = 5V

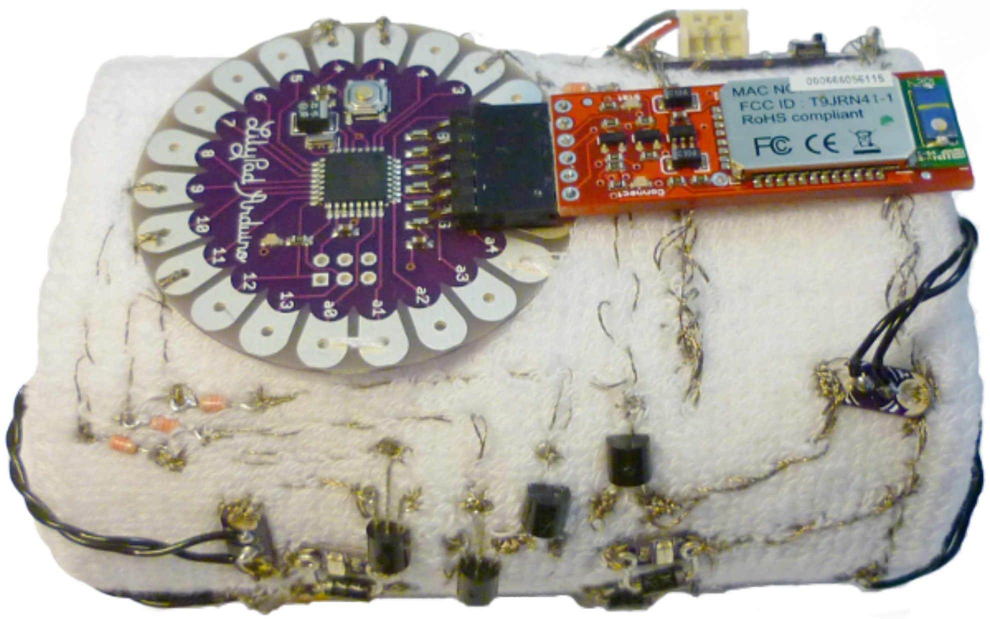
THRPIEZO = ?

$$5\frac{10}{10+1000+6800} \leq THRPIEZO \leq 5\frac{1010}{10+1000+6800}$$

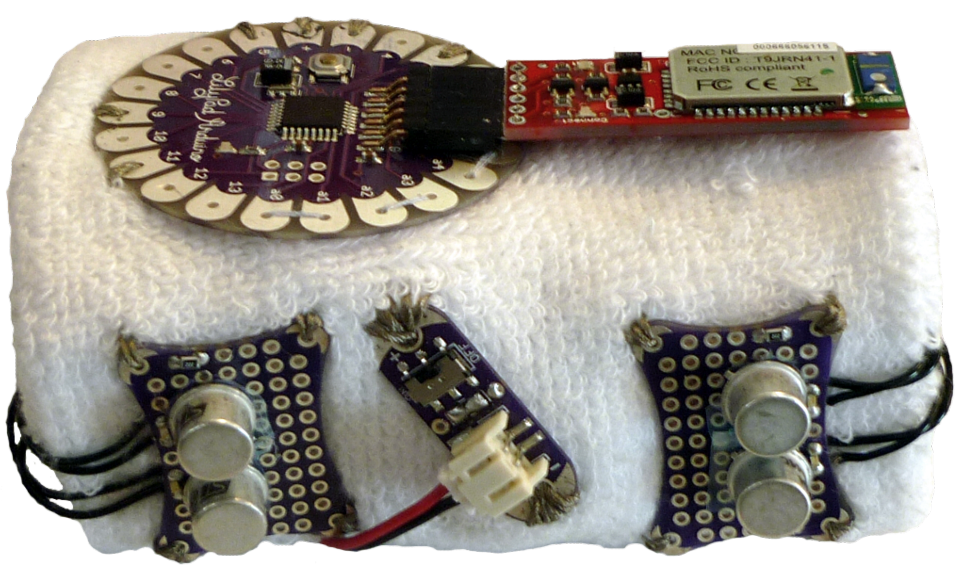
$$6mV \leq THRPIEZO \leq 646mV$$

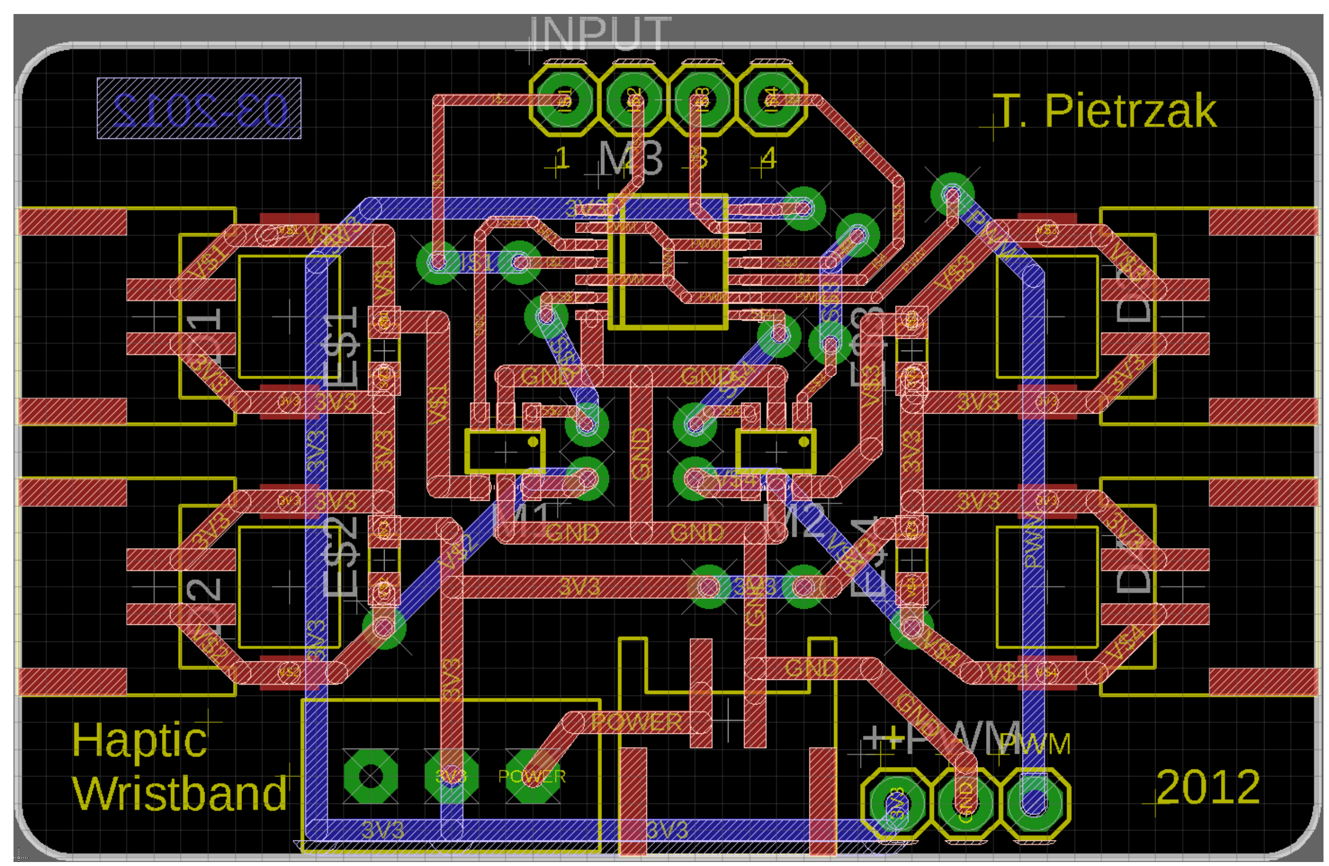
Bracelet tactile



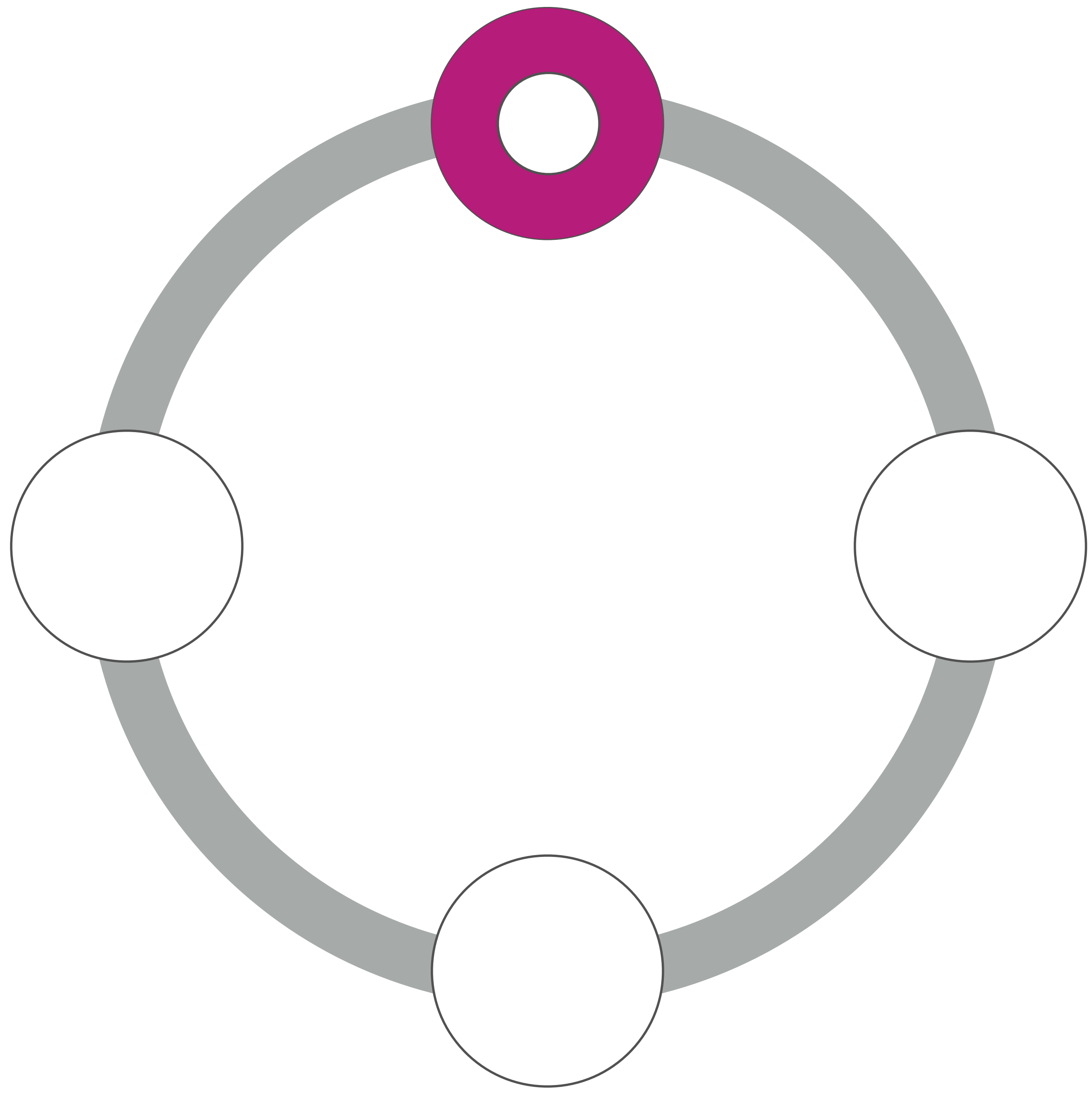



T. Pietrzak

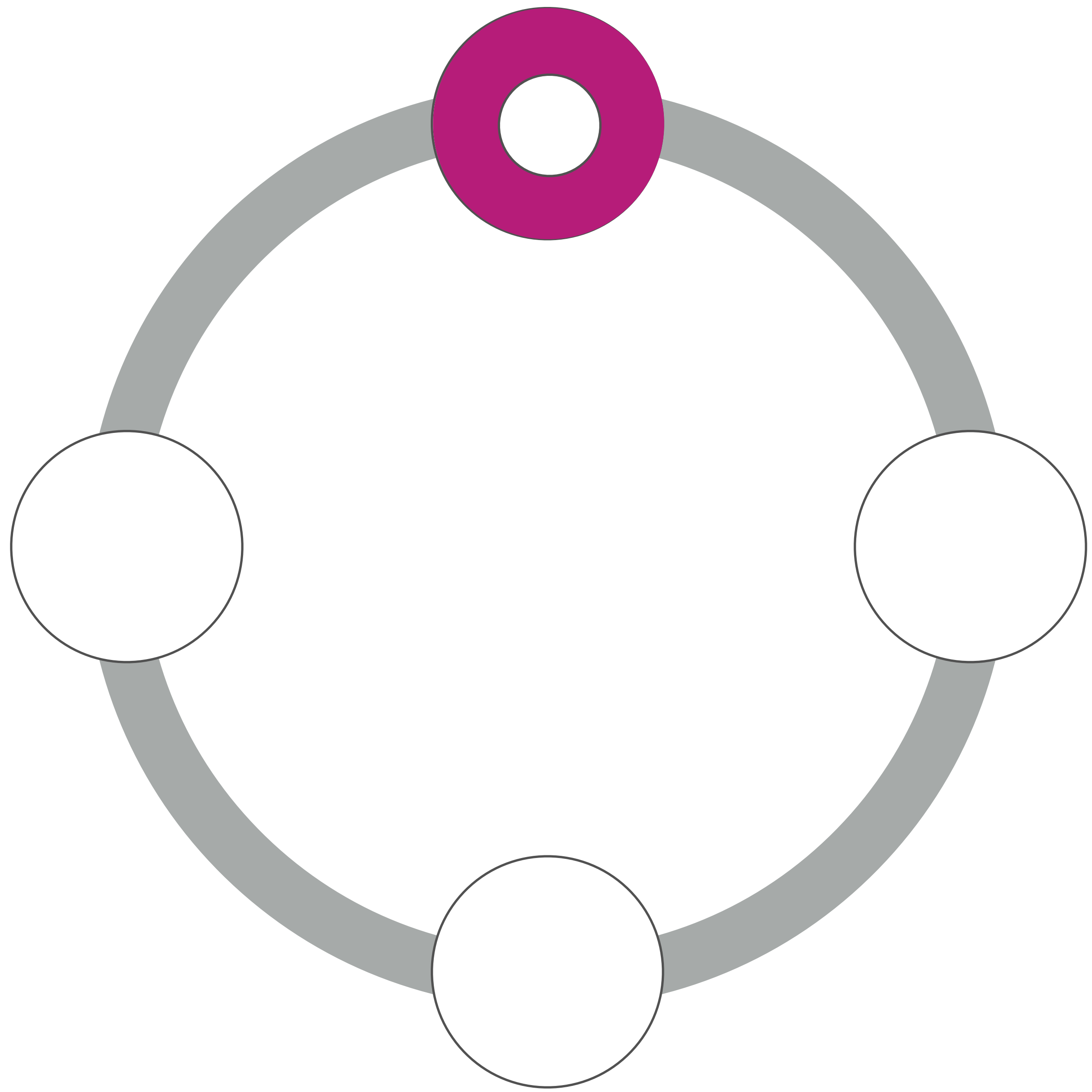


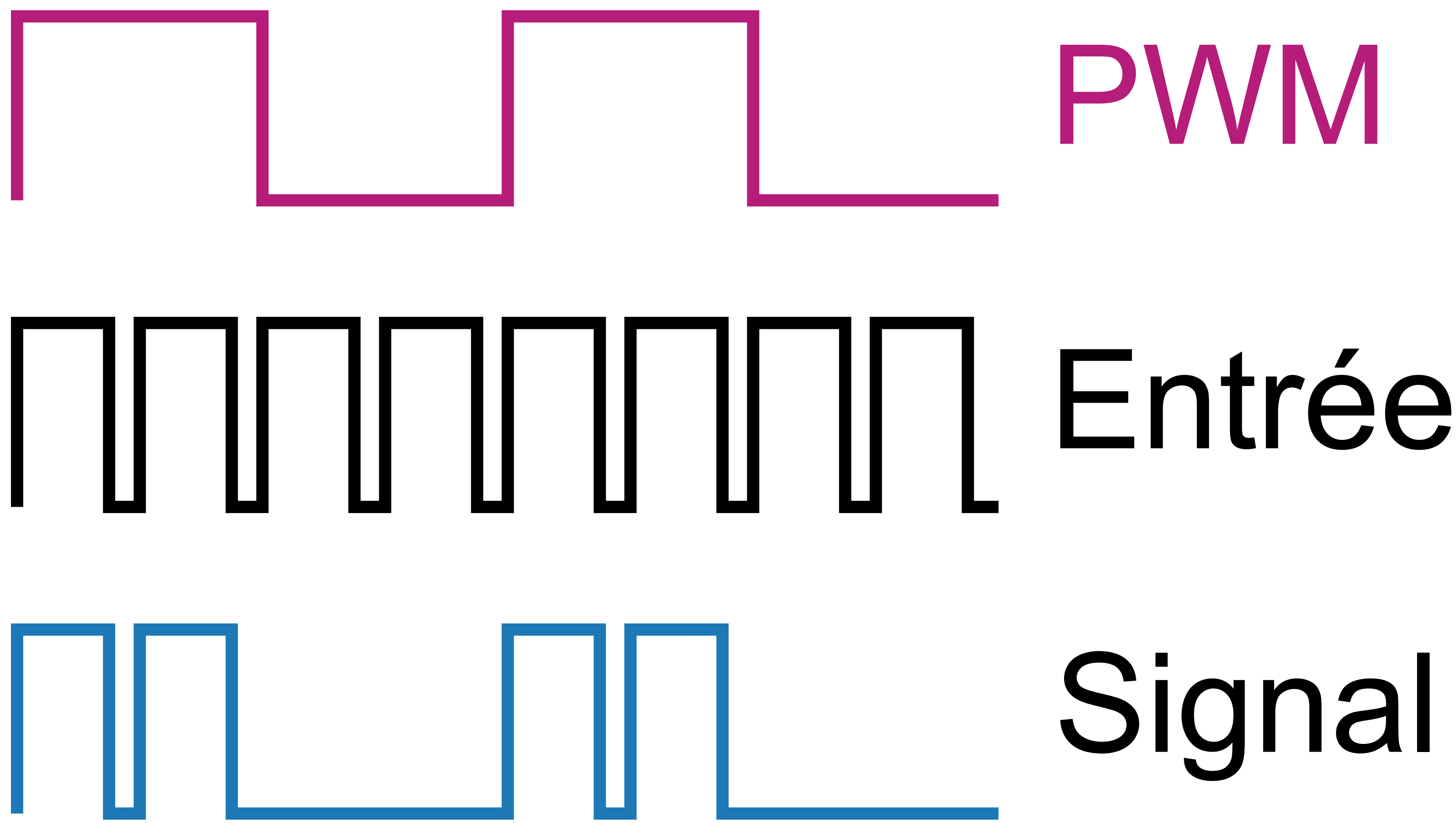

INPUT
T. Pietrzak
M3
Haptic
Wristband
PWM
2012

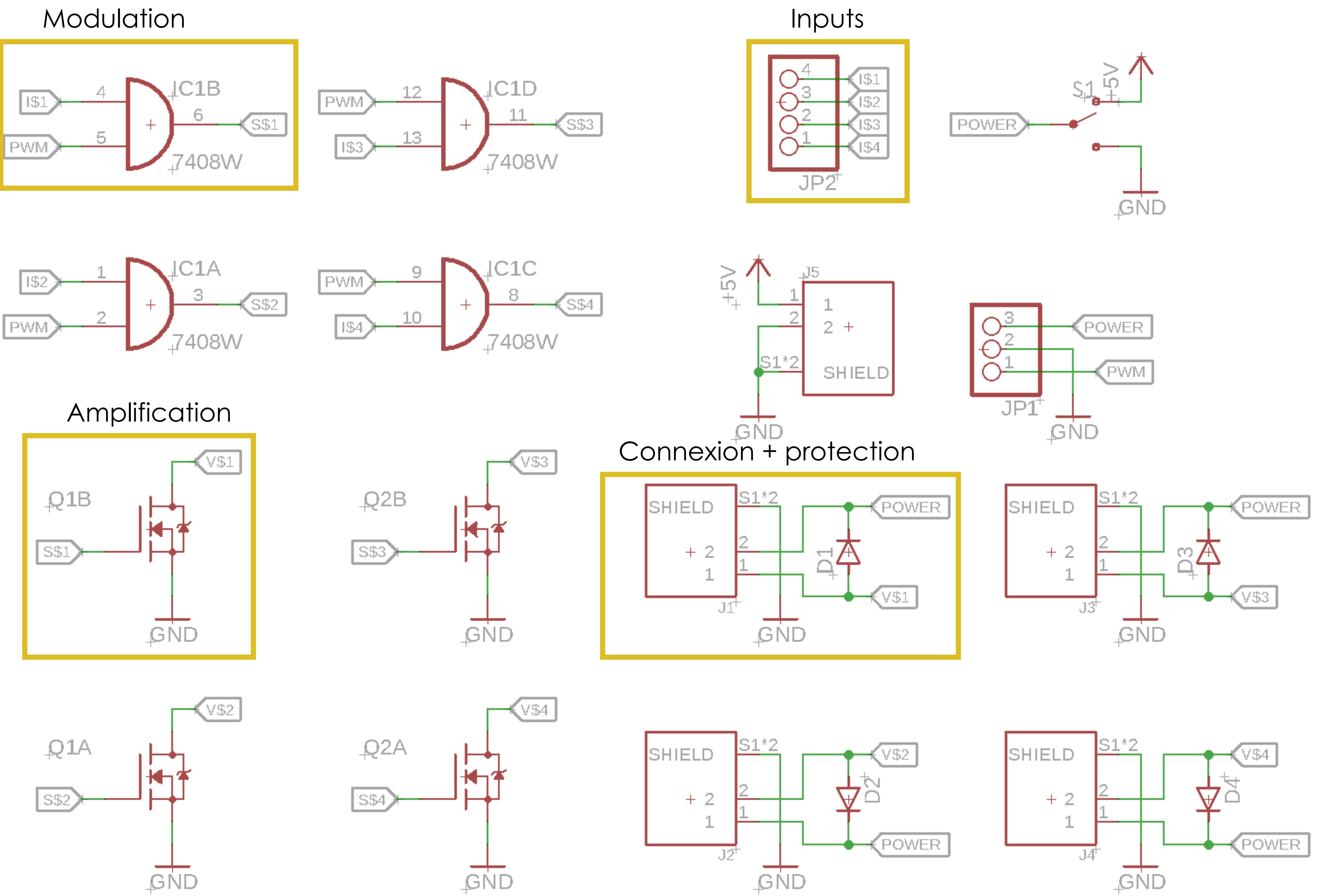
Vibrations fantômes



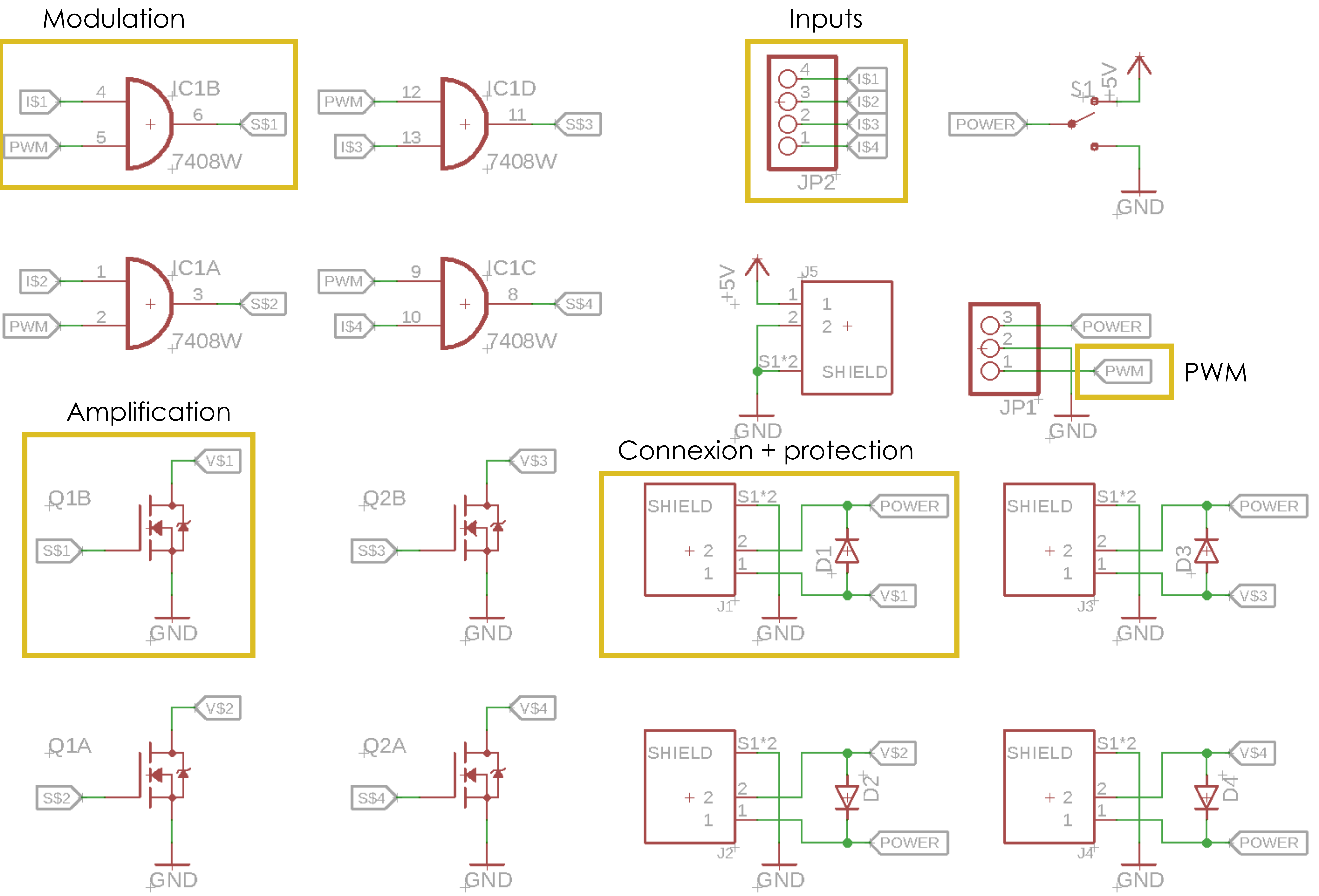
Vibrations fantômes




PWM
Entrée
Signal



Modulation
Inputs
Amplification
Connexion + protection
IC1B
IC1D
IC1A
IC1C
7408W
I$1
I$2
I$3
I$4
PWM
S$1
S$2
S$3
S$4
JP2
S1
+5V
POWER
GND
J5
SHIELD
S1*2
JP1
Q1B
Q2B
Q1A
Q2A
V$1
V$2
V$3
V$4
D1
D2
D3
D4
J1
J2
J3
J4


Modulation
Inputs
Amplification
Connexion + protection
PWM
IC1B
IC1D
IC1A
IC1C
7408W
I$1
I$2
I$3
I$4
PWM
S$1
S$2
S$3
S$4
JP2
JP1
J5
S1
+5V
POWER
GND
SHIELD
S1*2
Q1B
Q2B
Q1A
Q2A
V$1
V$2
V$3
V$4
J1
J2
J3
J4
D1
D2
D3
D4