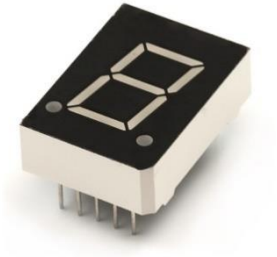
CIRCUITOS DIGITALES Y MICROCONTROLADORES 2022

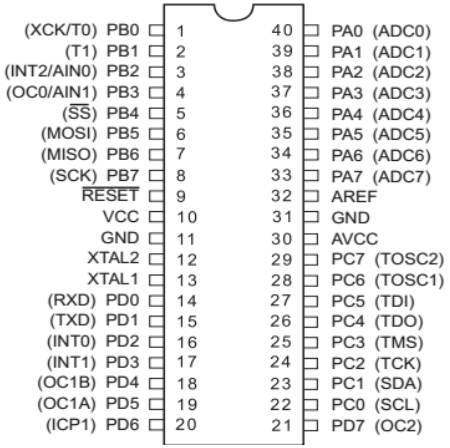
Facultad de Ingeniería UNLP

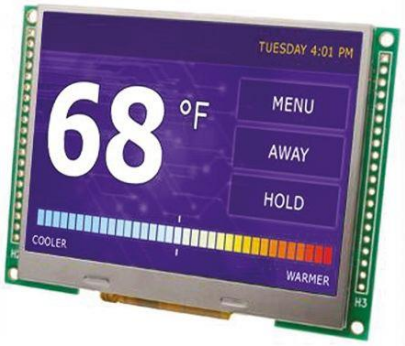
Puertos de entrada salida
Características eléctricas

Ing. José Juárez

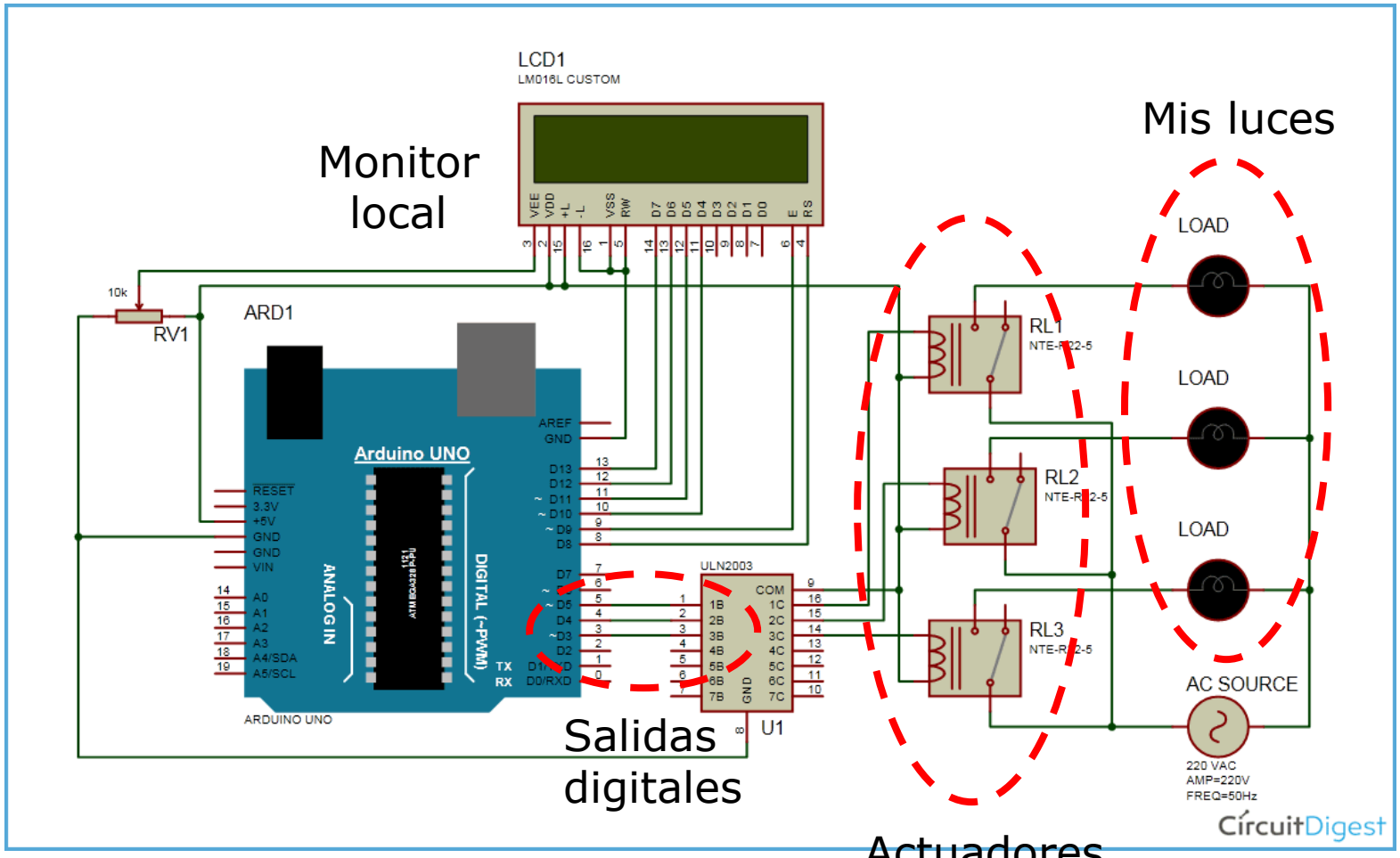
¿Puertos de Entrada-Salida? … Hablemos de Hardware







Un ejemplo motivador
Domótica Fácil



Registros de los Puertos I/O

¿Donde están los registros I/O del puerto B ?

mundo lógico

descripción

PORTB – Port B Data Register Address I/O: 0x05

Bit	7	6	5	4	3	2	1	0	
	PORTB7	PORTB6	PORTB5	PORTB4	PORTB3	PORTB2	PORTB1	PORTB0	PORTB
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

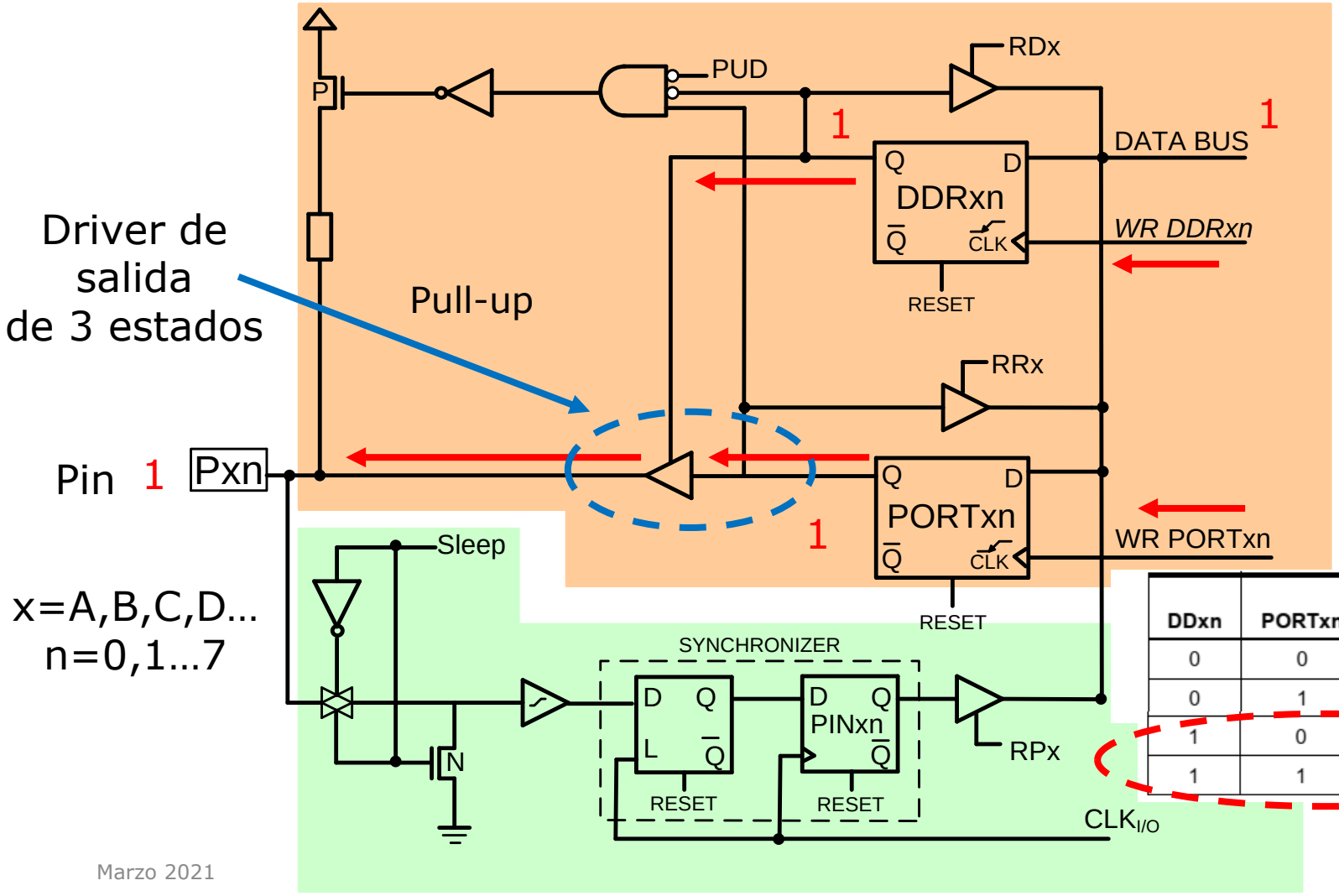
DDRB – Port B Data Direction Register Address I/O: 0x04

Bit	7	6	5	4	3	2	1	0	
	DDB7	DDB6	DDB5	DDB4	DDB3	DDB2	DDB1	DDB0	DDRB
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

PINB – Port B Input Pins Address Address I/O: 0x03

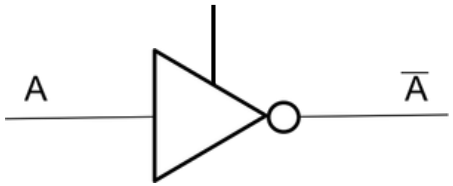
Bit	7	6	5	4	3	2	1	0	
	PINB7	PINB6	PINB5	PINB4	PINB3	PINB2	PINB1	PINB0	PINB
Read/Write	R	R	R	R	R	R	R	R	
Initial Value	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	

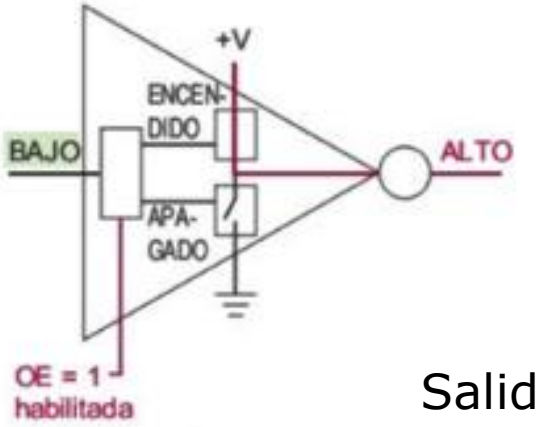
Registros de los Puertos I/O



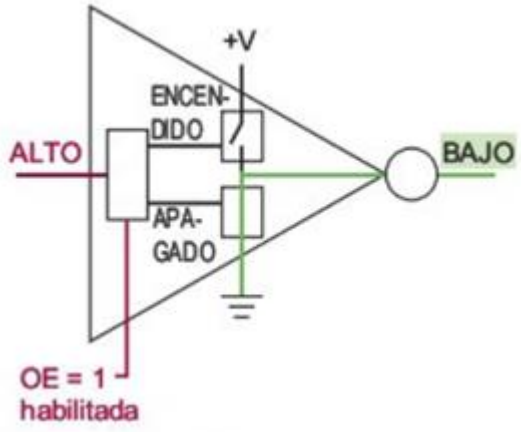
DDxn	PORTxn	I/O	Pull-up
0	0	Input	No
0	1	Input	Yes
1	0	Output	No
1	1	Output	No

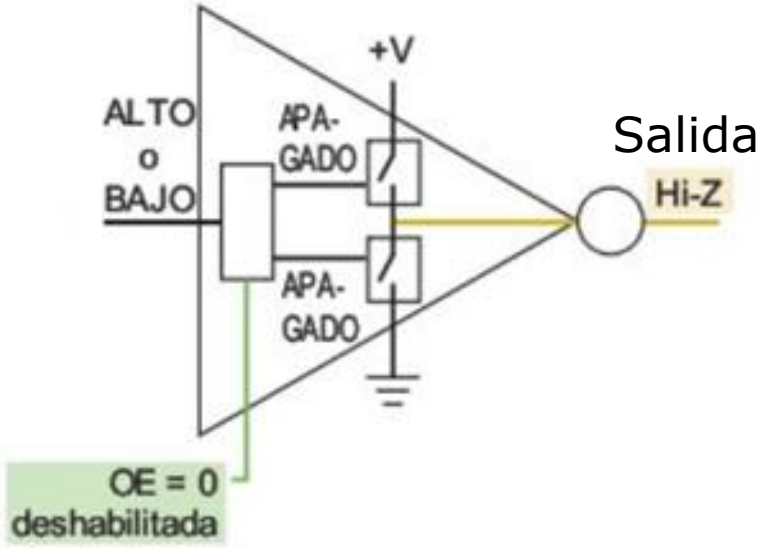
Driver de salida de 3 estados





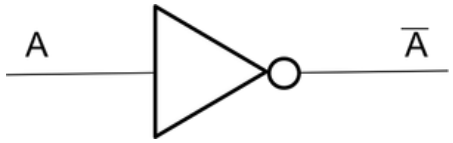
Salida
push-pull



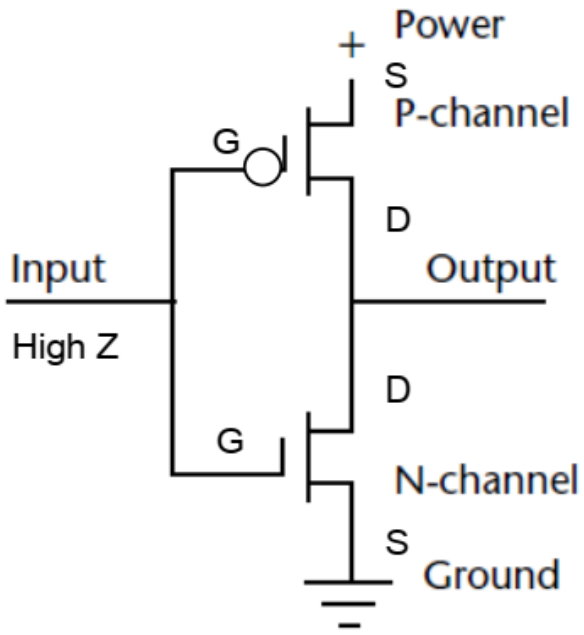


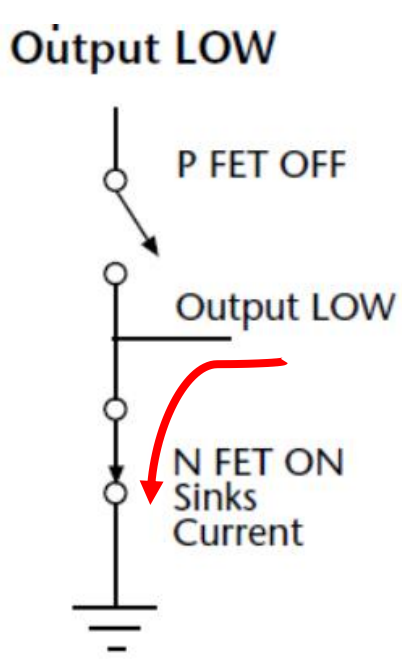
Repasar de la bibliografía:
Sistemas Digitales: Principios y aplicaciones, R. Tocci

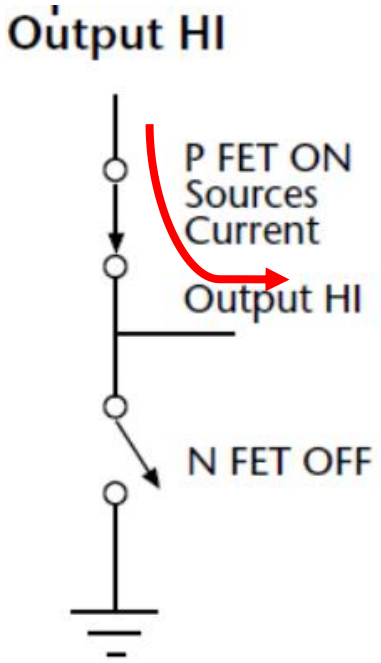
Introducción a la lógica CMOS



- Inversor CMOS <u>IDEAL</u>







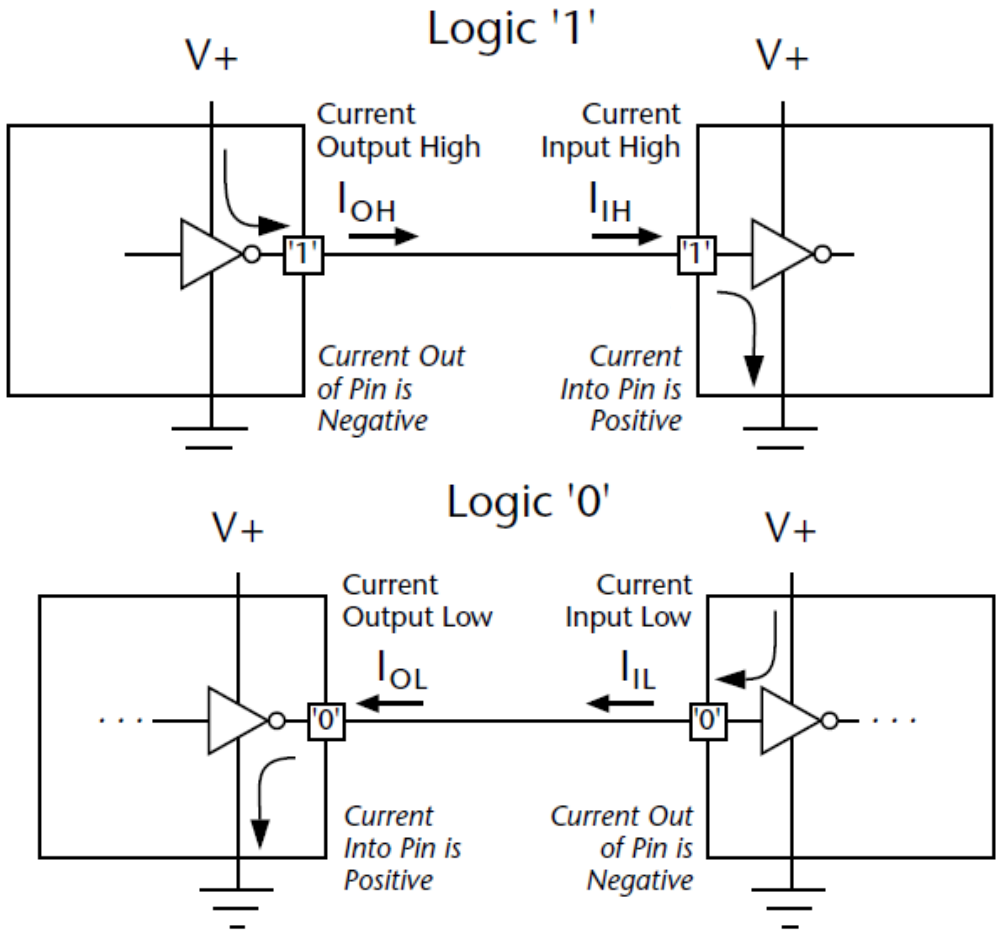
- CMOS(Complementary MOSFET)
- MOSFET(Metal Oxide Semiconductor Field Effect Transistor)

Repasar CMOS de la bibliografía: *Sistemas Digitales: Principios y aplicaciones, R.* Tocci el CH8

Introducción a la lógica CMOS

Por convención:
el signo de IOH se toma (-)
el signo de IIH se toma (+)

- Conexión entre dos dispositivos CMOS y sentido de la corriente



Capacidad de carga de una salida (Fan-Out):

-Tipo y # de cargas conectadas
-características DC y AC de las cargas:

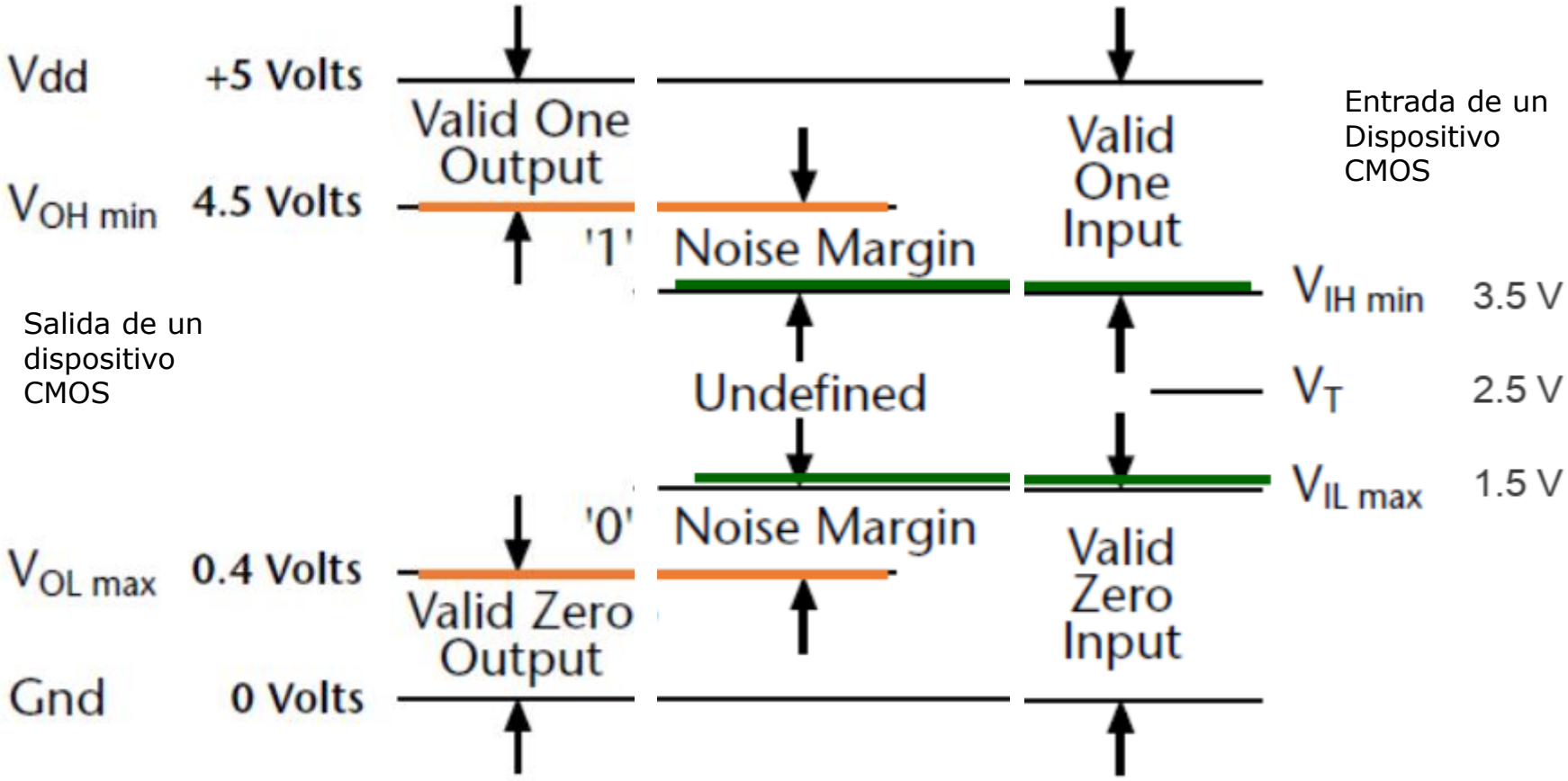
Características DC:
-I_{OLmax}, I_{OHmax}
-I_{ILmax}, I_{IHmax}

Características AC:
-CL: capacidad de carga a la salida (test)
-Cin: capacidad de entrada
-Cstray: Capacidad del cableado y PCB

CL > Cin1+Cin2+…+Cstray

Introducción a la lógica CMOS

- Valores de operación y margen de ruido (características DC) típicos en familias CMOS de 5V



Obtener valores de la Hoja de datos de cada dispositivo en particular

Especificación para AVR

- Valores de referencia ATMEGA328P:

28.2 DC Characteristics

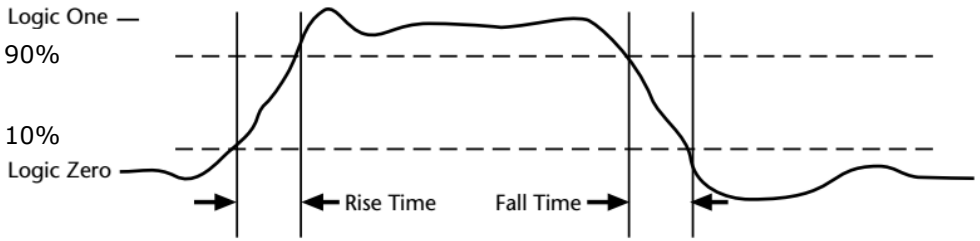
T_A = -40°C to 85°C, V_{CC} = 1.8V to 5.5V (unless otherwise noted)

Symbol	Parameter	Condition	Min.	Typ.	Max.	Units
V_{IL}	Input Low Voltage, except XTAL1 and $\overline{\text{RESET}}$ pin	V_{CC} = 1.8V - 2.4V V_{CC} = 2.4V - 5.5V	-0.5 -0.5		$0.2V_{CC}$ (1) $0.3V_{CC}$ (1)	V
V_{IH}	Input High Voltage, except XTAL1 and $\overline{\text{RESET}}$ pins	V_{CC} = 1.8V - 2.4V V_{CC} = 2.4V - 5.5V	$0.7V_{CC}$ (2) $0.6V_{CC}$ (2)		V_{CC} + 0.5 V_{CC} + 0.5	V
V_{OL}	Output Low Voltage (3) except RESET pin	I_{OL} = 20 mA, V_{CC} = 5V I_{OL} = 10 mA, V_{CC} = 3V			0.9 0.6	V
V_{OH}	Output High Voltage (4) except Reset pin	I_{OH} = -20 mA, V_{CC} = 5V I_{OH} = -10 mA, V_{CC} = 3V	4.2 2.3			V

Introducción a la lógica CMOS

- Temporización (características AC)

Tiempo de Subida
Tiempo de Bajada



Retardo de Propagación

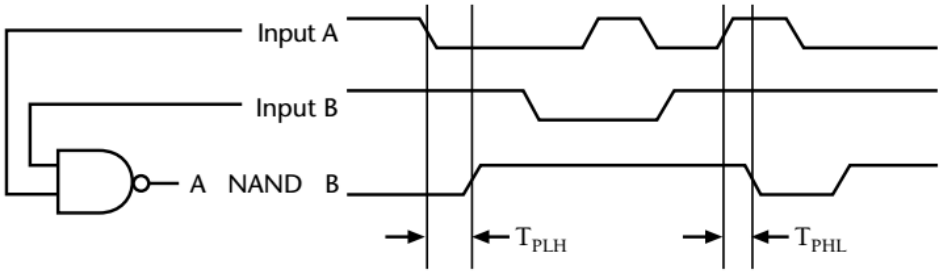
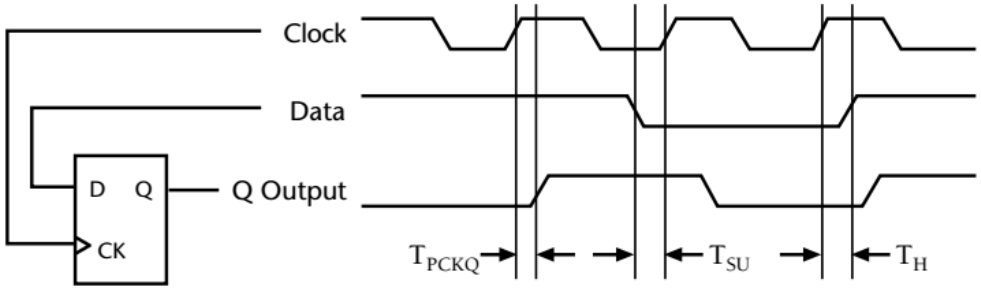


Figure 3-3: Propagation delay.

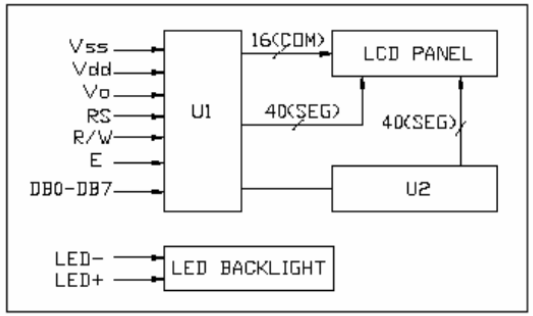
Tiempo de Setup
Tiempo de Hold

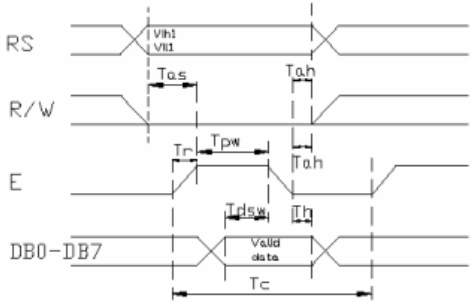


Introducción a la lógica CMOS

De la hoja de datos del Display
WH1602A-YGH-CTK.pdf
Familia TTL

- Ejemplo: quiero conectar mi MCU con este dispositivo digital:





5、DC CHARACTERISTICS (Ta=25℃; Vdd=5.0V±5%,Vss=0V)

Item	Symbol	Test Condition	Min.	Typ.	Max.	Unit
Operating Voltage	Vdd	--	--	5.0	--	V
LCD Voltage	Vlcd	Vdd-Vo	--	5.0	--	V
Operating Current	Idd	Vdd=5.0V	--	1.2	1.8	MA
Input "High" Voltage (1) (Except OSC1)	Vih1	--	2.2	--	Vdd	V
Input "Low" Voltage (1) (Except OSC1)	Vil1	--	-0.3	--	0.6	V
Input "High" Voltage (2) (OSC1)	Vih2	--	Vdd-1.0	--	Vdd	V
Input "Low" Voltage (2) (OSC1)	Vil2	--	-0.2	--	1.0	V
Output "High" Voltage (1) (D0-D7)	Voh1	Ioh=-0.205mA	2.4	--	--	V
Output "Low" Voltage (1) (D0-D7)	Vol1	Iol=1.2mA	--	--	0.4	V

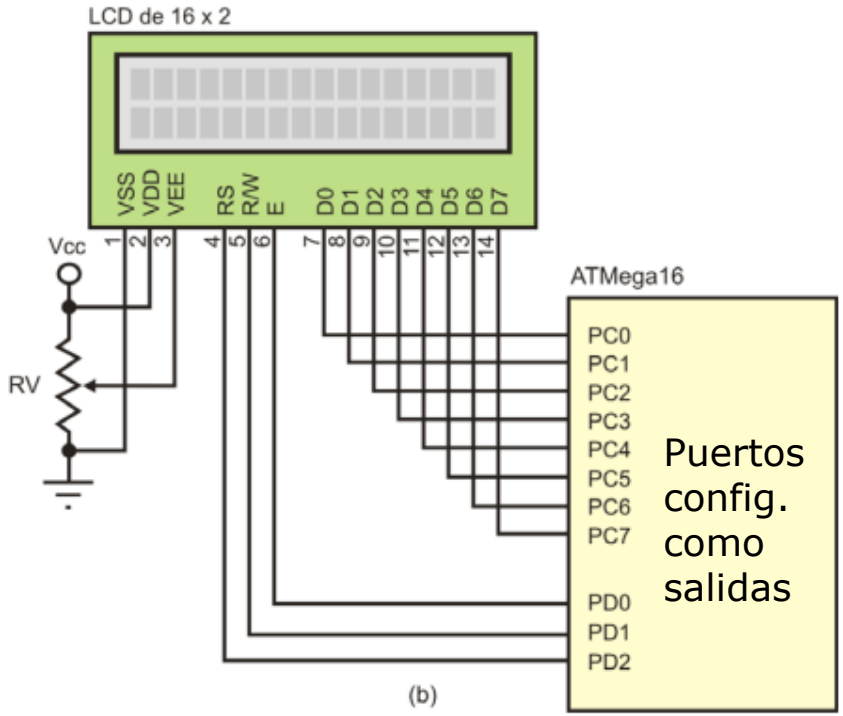
8、AC CHARACTERISTICS (Vdd=5.0V±5%,Vss=0V ,Ta=25℃)

(Write mode)

Characteristic	Symbol	Min.	Typ.	Max.	Unit
E Cycle Time	Tc	500	--	--	ns
E Rise/Fall Time	Tr,Tf	--	--	25	ns
E Pulse Width (High, Low)	Tpw	220	--	--	ns
R/W and RS Set-up Time	Tas	40	--	--	ns
R/W and RS Hold Time	Tah	10	--	--	ns
Data Set-up Time	Tdsw	60	--	--	ns
Data Hold Time	Th	10	--	--	ns

Introducción a la lógica CMOS

- Solución:

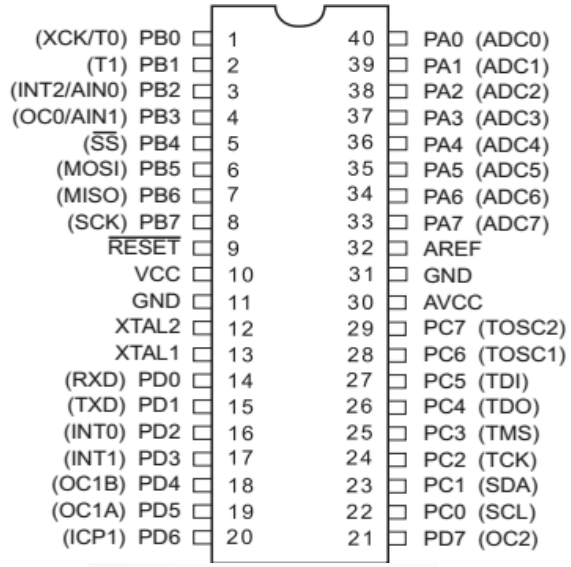


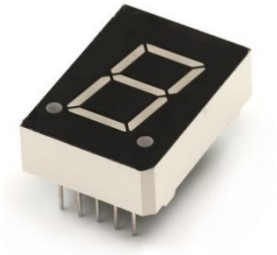
¿Son eléctricamente compatibles?

Repasar interconexión de familias lógicas del libro de Tocci el CH8

Introducción a la lógica CMOS

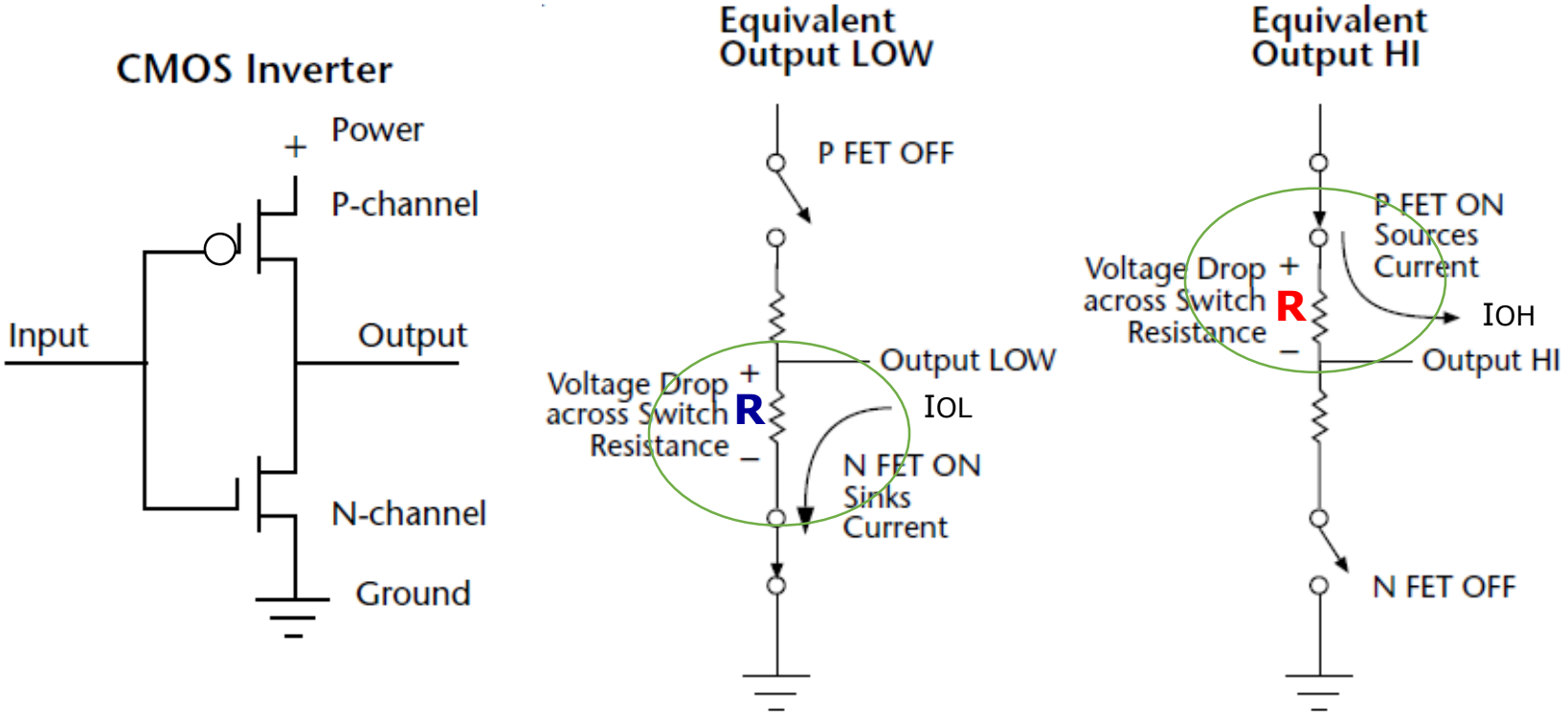
- Ahora quiero conectar mi MCU con estos periféricos





Características eléctricas de salidas CMOS

- Inversor CMOS real



$V_{OL} = I_{OL}.R$

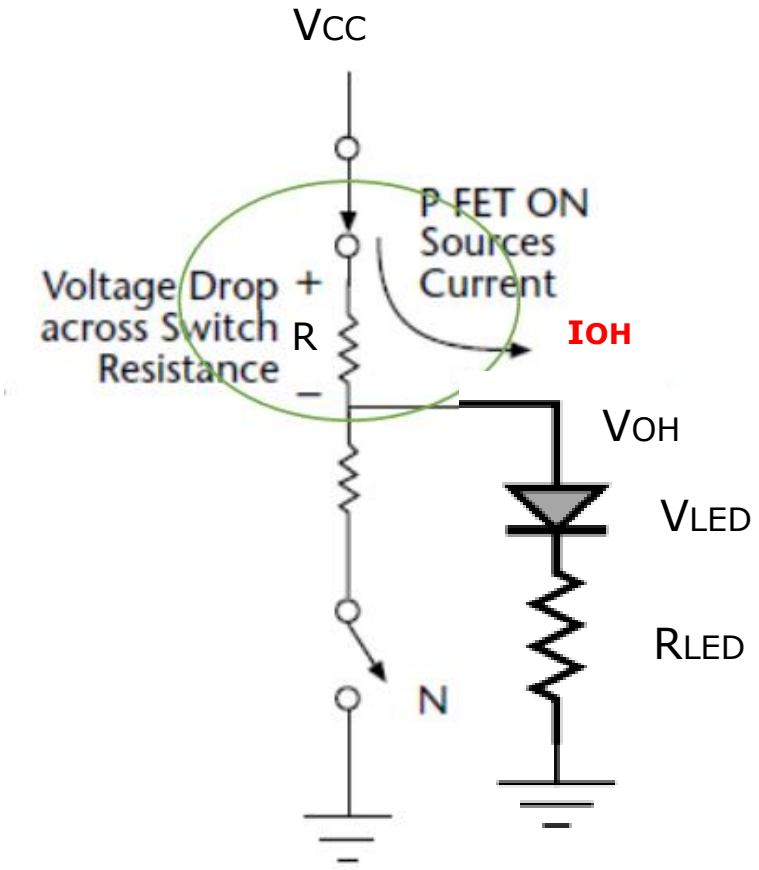
$P_{OL} = (I_{OL})^2.R$ [W]

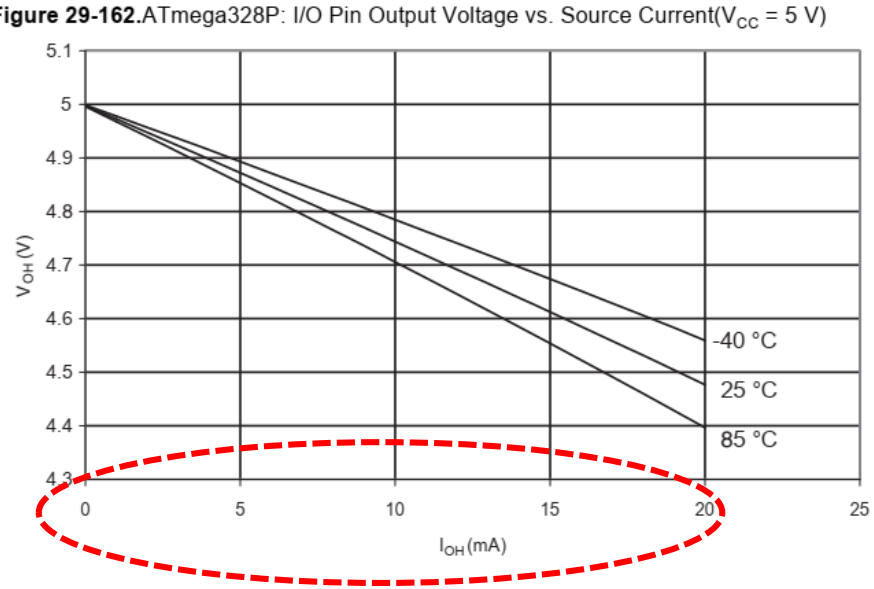
$V_{OH} = V_{CC} - I_{OH}.R$

$P_{OH} = (I_{OH})^2.R$ [W]

Especificación para AVR

- Corriente de salida vs Tensión de Salida: “1”





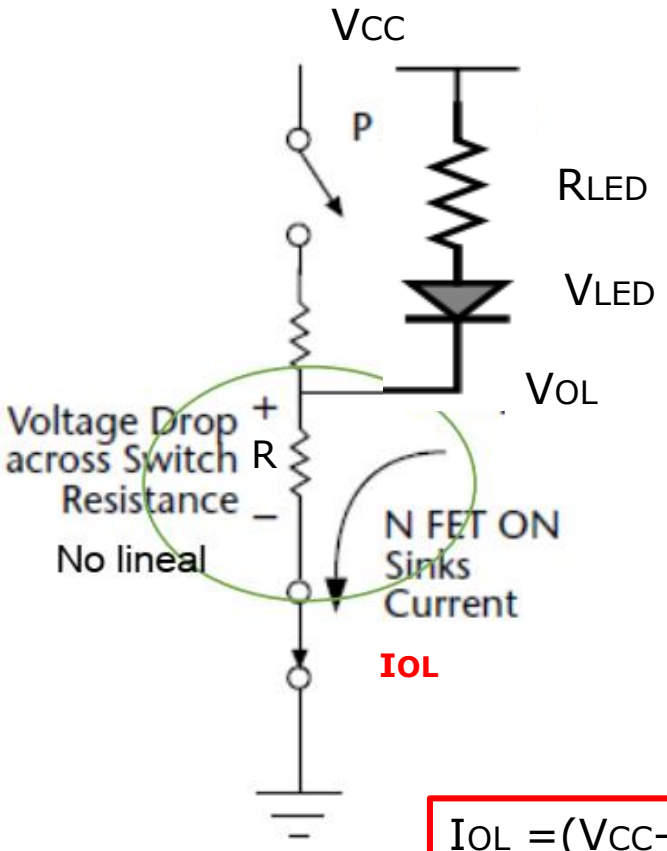
Zonas seguras de operación

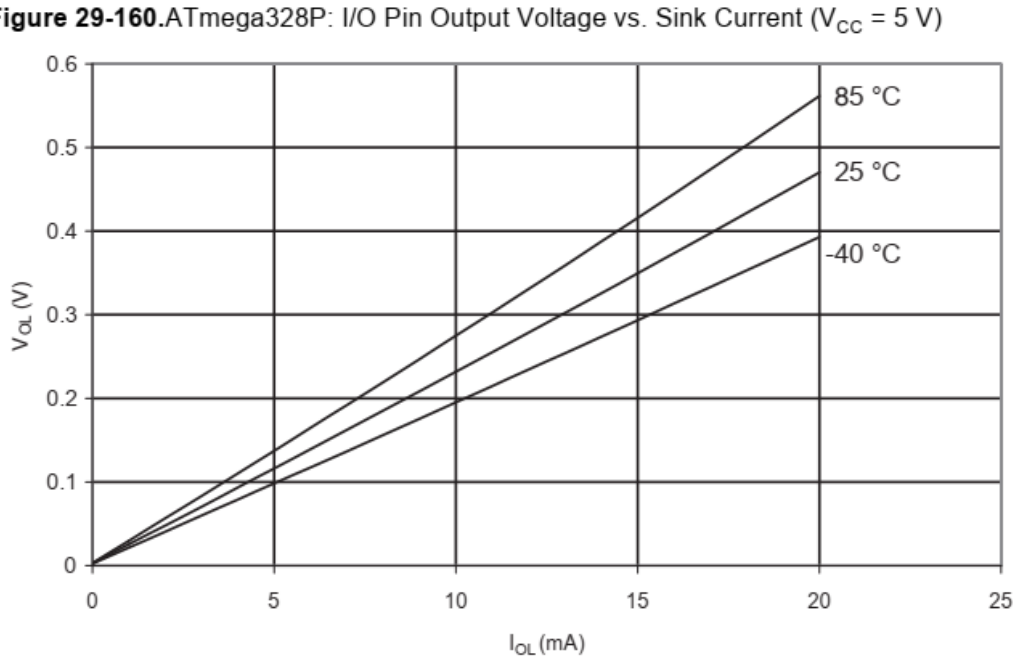
$I_{OH} = (V_{OH} - V_{LED}) / R_{LED}$

$V_{OH} = V_{DD} - I_{OH}.R$

Especificación para AVR

- Corriente de salida vs Tensión de Salida: “0”





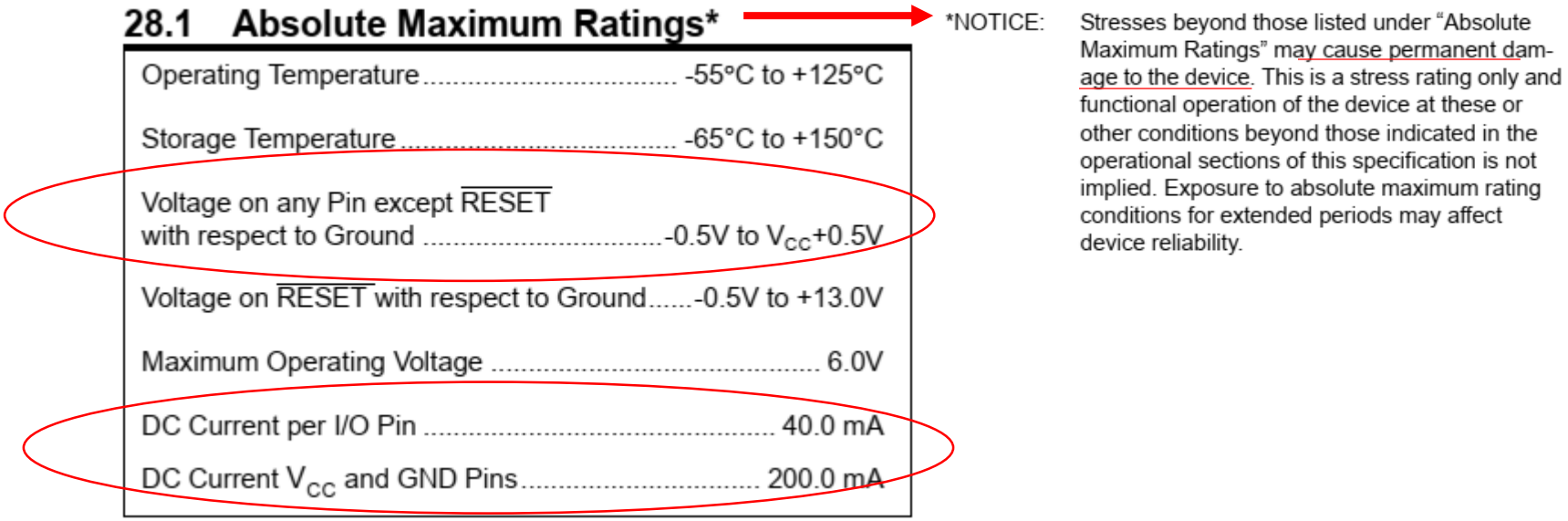
Zonas seguras de operación

$I_{OL} = (V_{CC} - V_{OL} - V_{LED}) / R_{LED}$

$V_{OL} = I_{OH} . R$

Especificación para AVR

- Condiciones Máximas para Operación:



28.1 Absolute Maximum Ratings*

Operating Temperature	-55°C to +125°C
Storage Temperature	-65°C to +150°C
Voltage on any Pin except $\overline{\text{RESET}}$ with respect to Ground	-0.5V to V_{CC}+0.5V
Voltage on $\overline{\text{RESET}}$ with respect to Ground	-0.5V to +13.0V
Maximum Operating Voltage	6.0V
DC Current per I/O Pin	40.0 mA
DC Current V_{CC} and GND Pins	200.0 mA

*NOTICE: Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or other conditions beyond those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

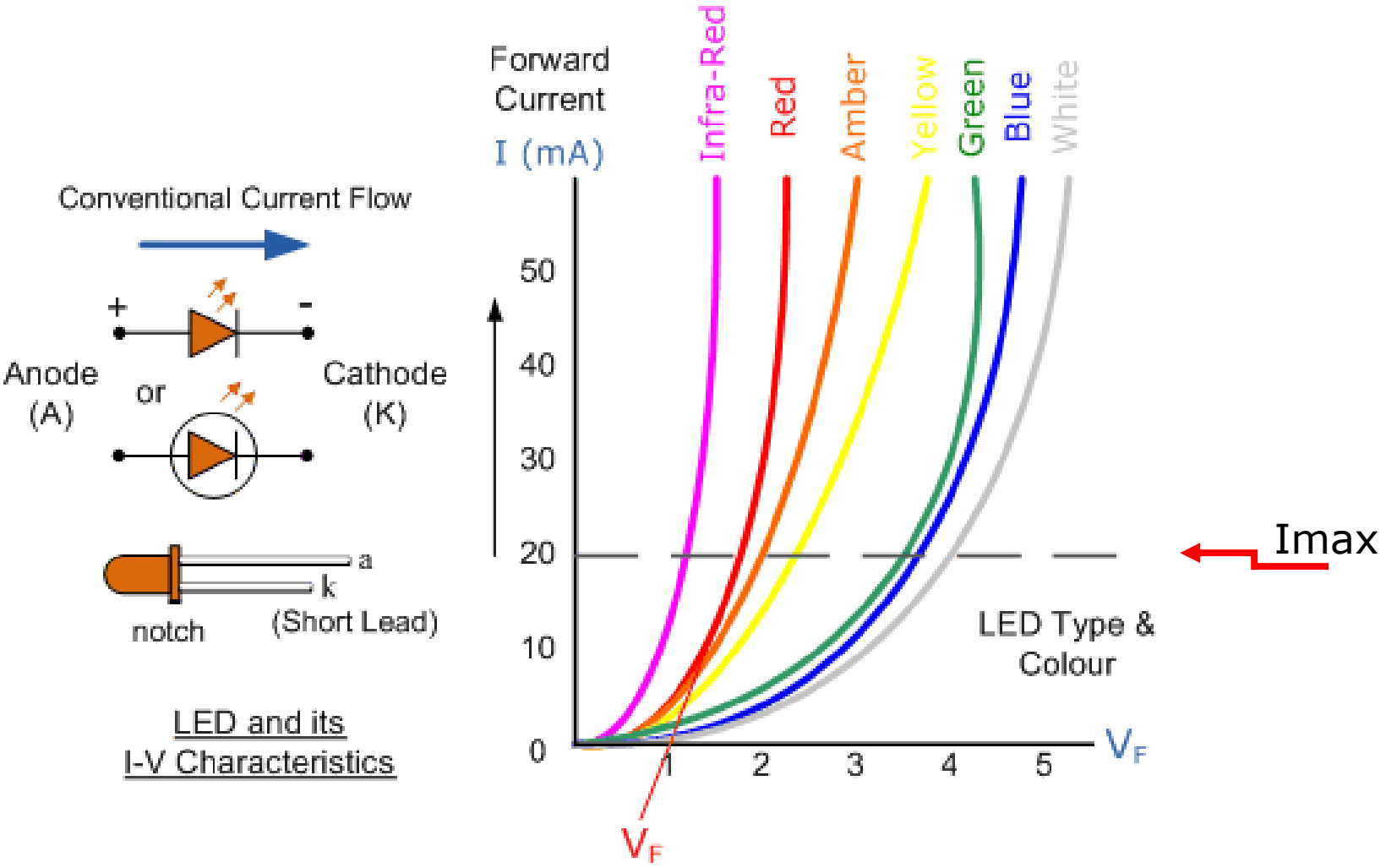
Especificación para AVR

- Condiciones Máximas para Operación:

V_{OL}	Output Low Voltage[3] except RESET pin	I_{OL} = 20 mA, V_{CC} = 5V I_{OL} = 10 mA, V_{CC} = 3V			0.9 0.6	V
V_{OH}	Output High Voltage[4] except Reset pin	I_{OH} = -20 mA, V_{CC} = 5V I_{OH} = -10 mA, V_{CC} = 3V	4.2 2.3			V

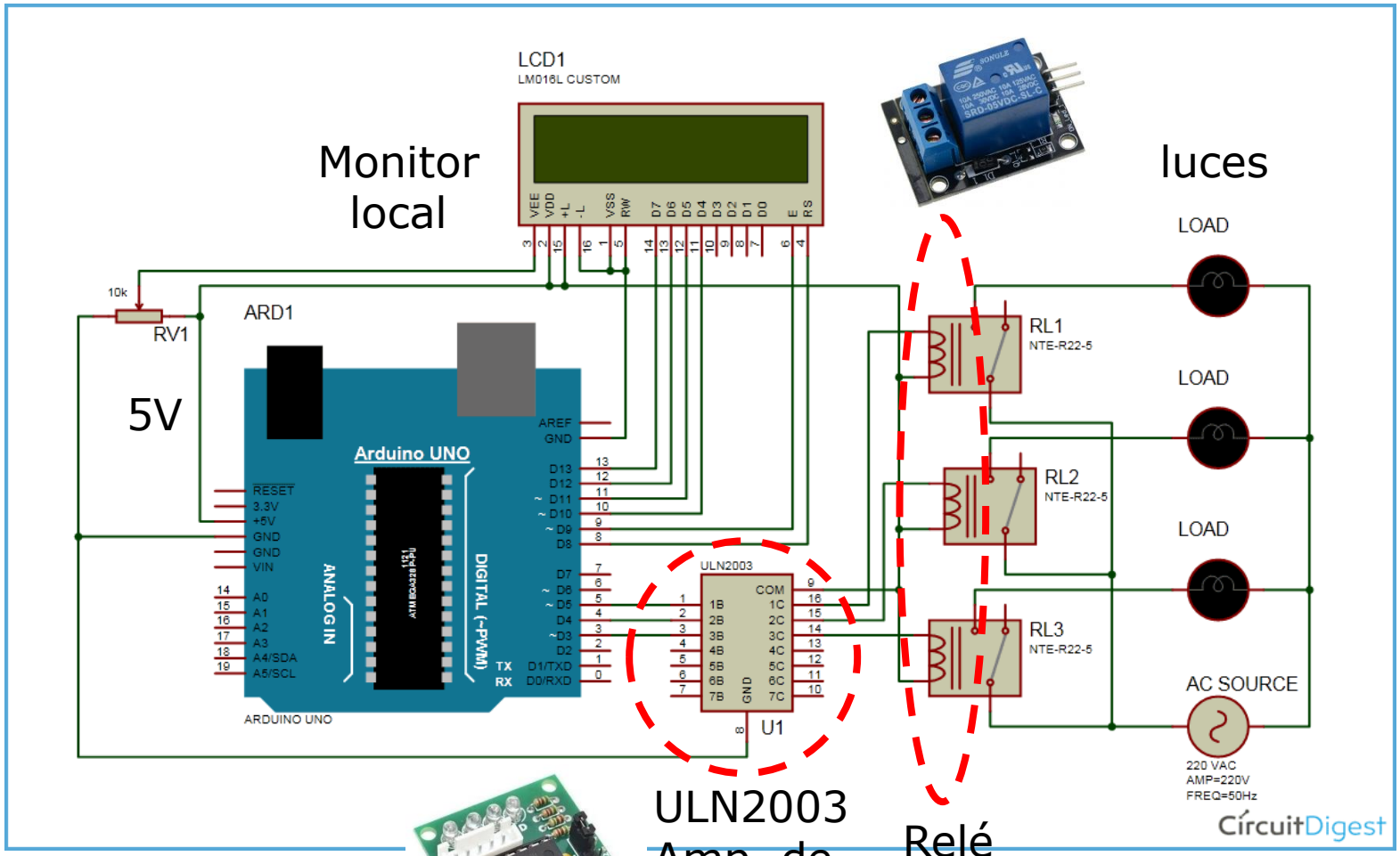
Notes:
1. "Max" means the highest value where the pin is guaranteed to be read as low
2. "Min" means the lowest value where the pin is guaranteed to be read as high
3. Although each I/O port can sink more than the test conditions (20 mA at V_{CC} = 5V, 10 mA at V_{CC} = 3V) under steady state conditions (non-transient), the following must be observed:
   ATmega48PA/88PA/168PA/328P:
   1] The sum of all I_{OL}, for ports C0 - C5, ADC7, ADC6 should not exceed 100 mA.
   2] The sum of all I_{OL}, for ports B0 - B5, D5 - D7, XTAL1, XTAL2 should not exceed 100 mA.
   3] The sum of all I_{OL}, for ports D0 - D4, $\overline{\text{RESET}}$ should not exceed 100 mA.
   If I_{OL} exceeds the test condition, V_{OL} may exceed the related specification. Pins are not guaranteed to sink current greater than the listed test condition.
4. Although each I/O port can source more than the test conditions (20 mA at V_{CC} = 5V, 10 mA at V_{CC} = 3V) under steady state conditions (non-transient), the following must be observed:
   ATmega48PA/88PA/168PA/328P:
   1] The sum of all I_{OH}, for ports C0 - C5, D0- D4, ADC7, $\overline{\text{RESET}}$ should not exceed 150 mA.
   2] The sum of all I_{OH}, for ports B0 - B5, D5 - D7, ADC6, XTAL1, XTAL2 should not exceed 150 mA.
   If II_{OH} exceeds the test condition, V_{OH} may exceed the related specification. Pins are not guaranteed to source current greater than the listed test condition.

Diodos LED (Light Emitting Diode)

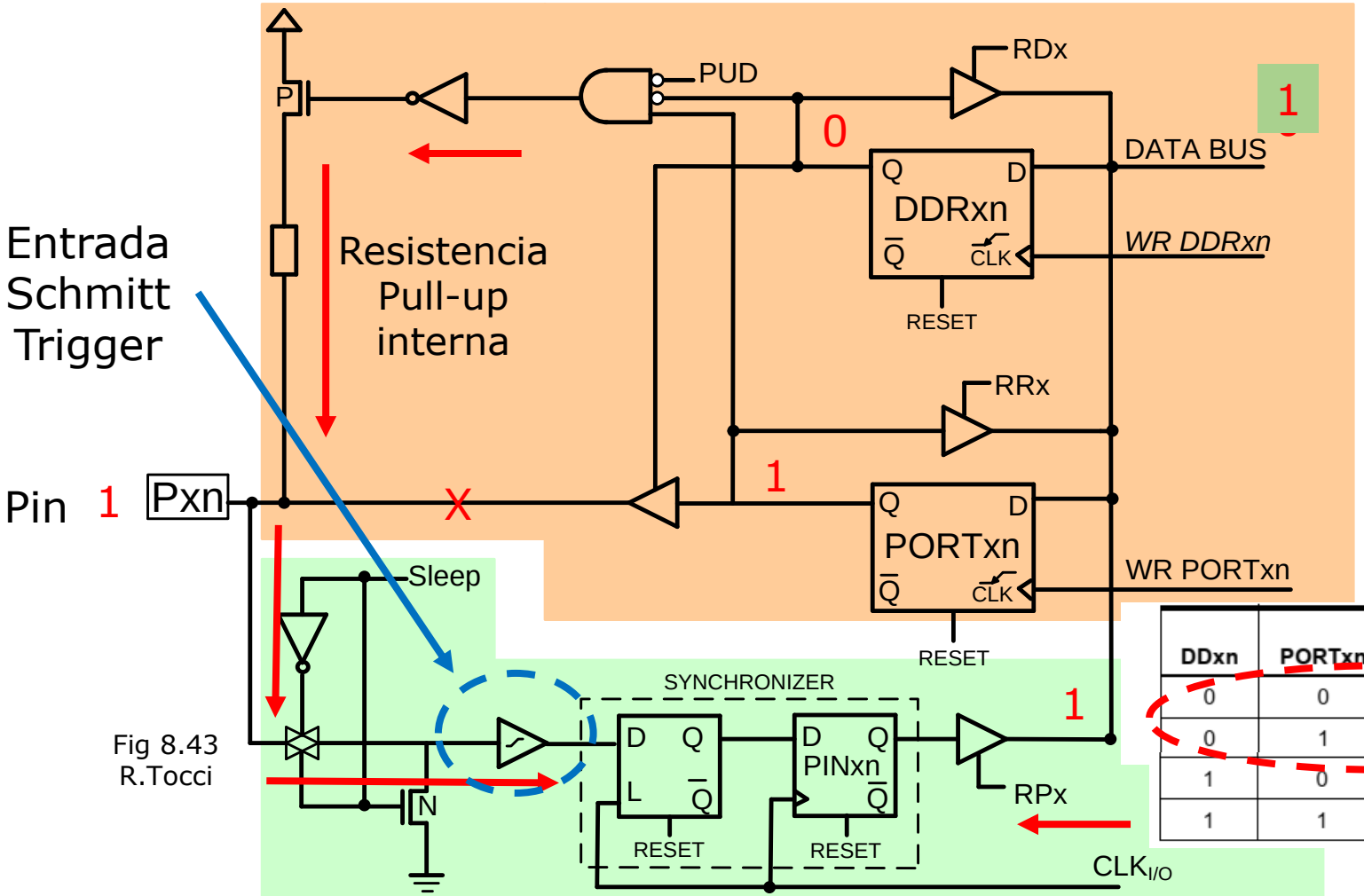


https://es.wikipedia.org/wiki/Ecuacion_de_Shockley

Un ejemplo motivador
Domótica Fácil



Registros de los Puertos I/O

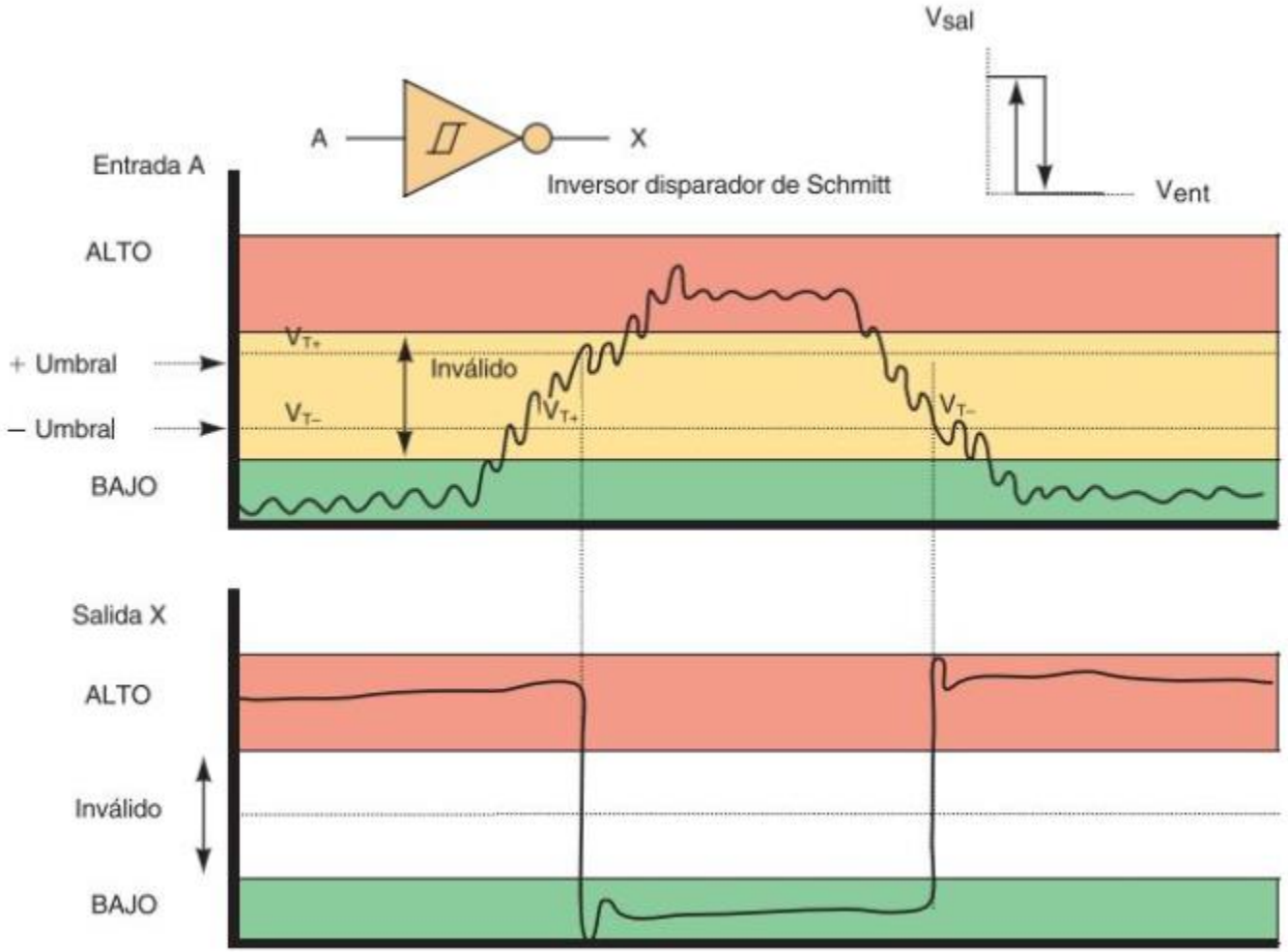


DDxn	PORTxn	I/O	Pull-up
0	0	Input	No
0	1	Input	Yes
1	0	Output	No
1	1	Output	No

Fig 8.43
R.Tocci

Entrada Schmitt Trigger

Permiten responder de manera confiable a entradas de variación lenta



Características eléctricas de entradas

28.2 DC Characteristics

T_A = -40°C to 85°C, V_{CC} = 1.8V to 5.5V (unless otherwise noted)

Symbol	Parameter	Condition	Min.	Typ.	Max.	Units
V_{IL}	Input Low Voltage, except XTAL1 and $\overline{\text{RESET}}$ pin	V_{CC} = 1.8V - 2.4V V_{CC} = 2.4V - 5.5V	-0.5 -0.5		$0.2V_{CC}$ (1) $0.3V_{CC}$ (1)	V
V_{IH}	Input High Voltage, except XTAL1 and $\overline{\text{RESET}}$ pins	V_{CC} = 1.8V - 2.4V V_{CC} = 2.4V - 5.5V	$0.7V_{CC}$ (2) $0.6V_{CC}$ (2)		V_{CC} + 0.5 V_{CC} + 0.5	V
I_{IL}	Input Leakage Current I/O Pin	V_{CC} = 5.5V, pin low (absolute value)			1	µA
I_{IH}	Input Leakage Current I/O Pin	V_{CC} = 5.5V, pin high (absolute value)			1	µA
R_{RST}	Reset Pull-up Resistor		30		60	kΩ
R_{PU}	I/O Pin Pull-up Resistor		20		50	kΩ

V_{IL}=1.5V @Vcc=5V
V_{IH}=3V @Vcc=5V

Características eléctricas de entradas

Figure 29-163. ATmega328P: I/O Pin Input Threshold Voltage vs. V_{CC} (V_{IH}, I/O Pin read as '1

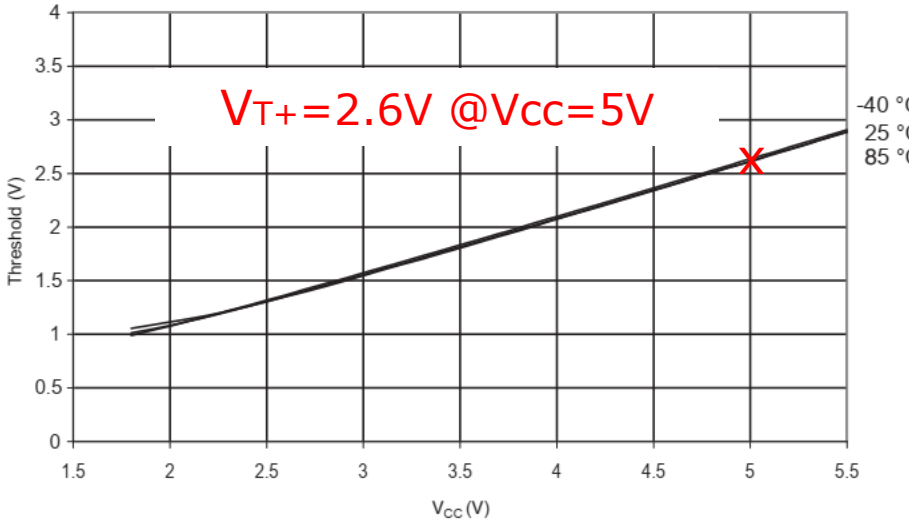


Figure 29-164. ATmega328P: I/O Pin Input Threshold Voltage vs. V_{CC} (V_{IL}, I/O Pin read as '0')

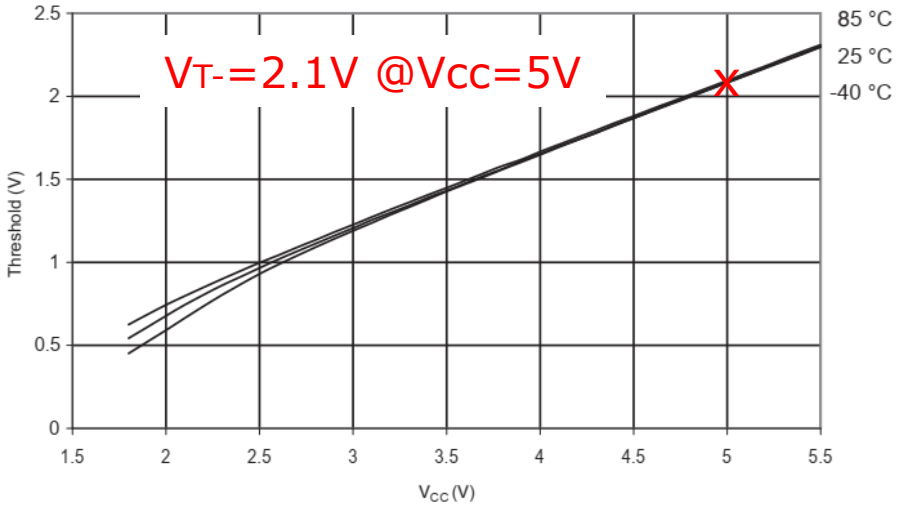
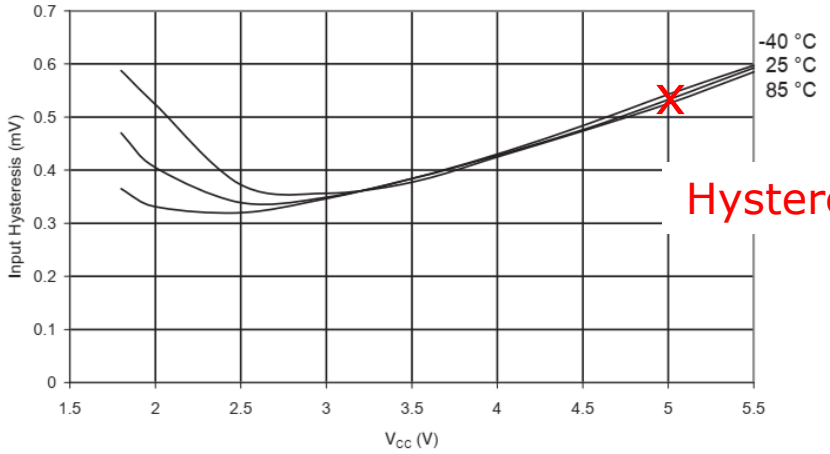


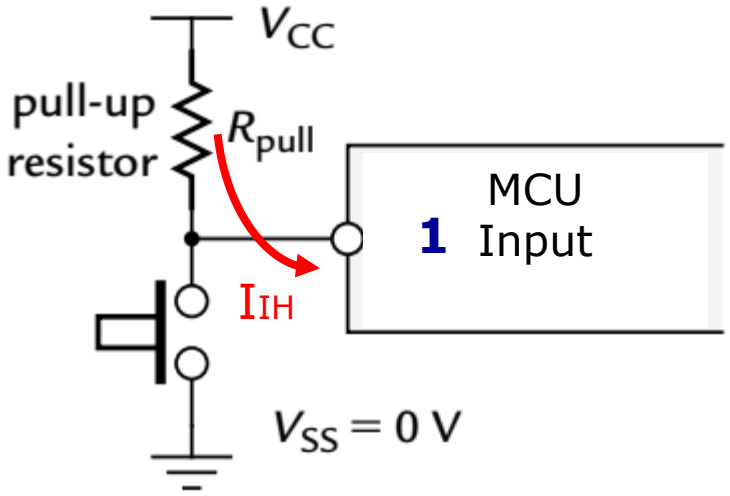
Figure 29-165. ATmega328P: I/O Pin Input Hysteresis vs. V_{CC}



Hysteresis ≅ 0.53V

Características eléctricas de entradas

- Utilizando un pulsador para establecer un valor lógico en una entrada



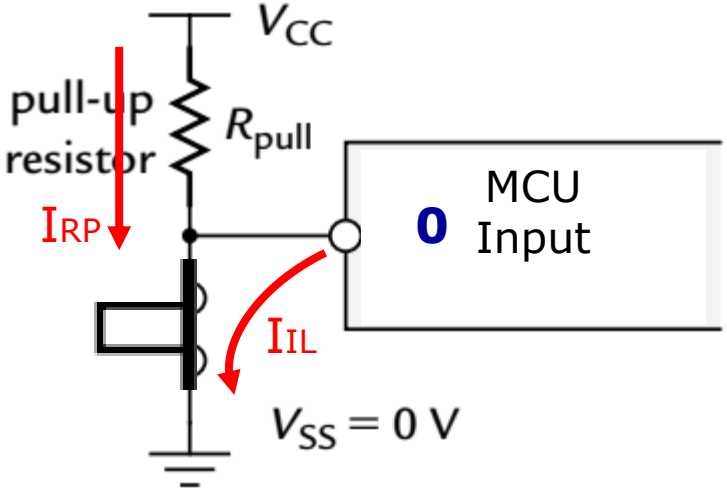
Pulsador no presionado: el estado lógico de la entrada es ALTO porque la misma se encuentra conectada a VCC a través de Rpull

de las especificaciones I_{IH} =1uA (despreciable)

Por lo tanto a la entrada tengo ≅ Vcc

Características eléctricas de entradas

- Utilizando un pulsador para establecer un valor lógico en una entrada



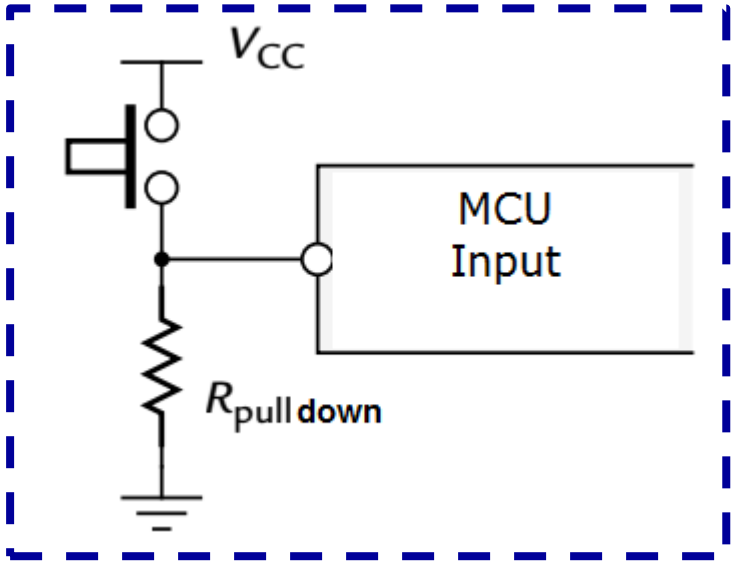
Pulsador presionado: el estado lógico de la entrada es BAJO porque la misma se encuentra conectada a 0V directamente

I_{IL} = 1uA (despreciable)
Por lo tanto a la entrada tengo ≅ 0V

$I_{RP} = V_{CC} / R_{PU} >> I_{IL}$

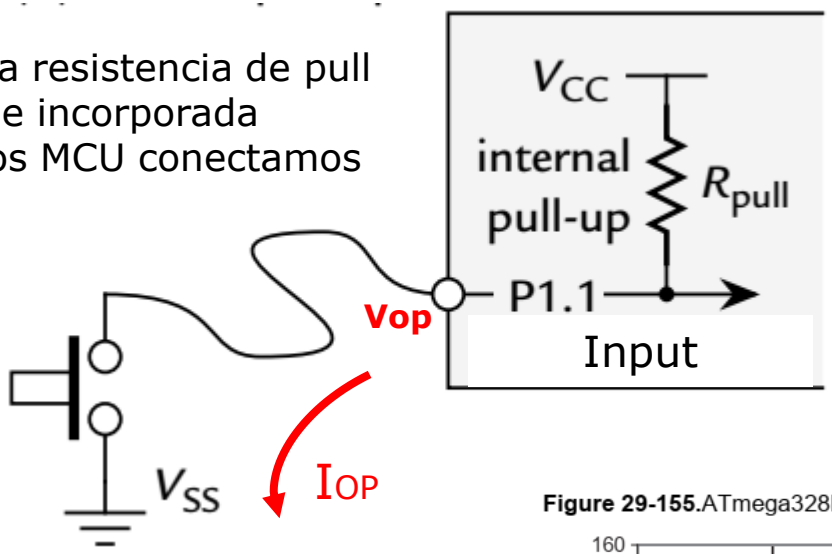
Generalmente R_{PU} =10KΩ

El mismo análisis puede realizarse utilizando una resistencia de Pull -Down



Características eléctricas de entradas

Si usamos la resistencia de pull up que viene incorporada dentro de los MCU conectamos así:



Ahora ya sabemos como funcionan:

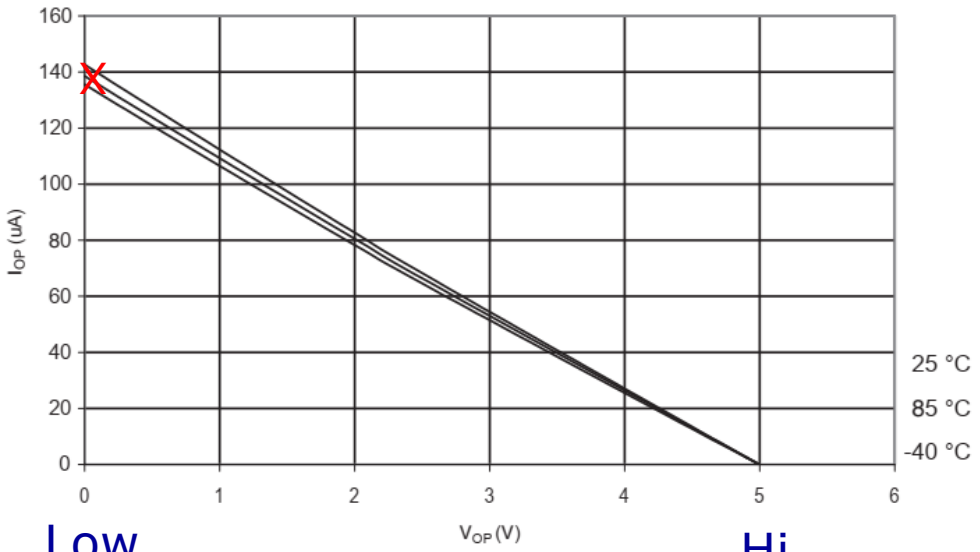
pinMode(x,[INPUT,INPUT_PULLUP,OUTPUT])

digitalRead(x)

digitalWritre(x, [0,1])

Para saber cuando vale I_{IL} y I_{IHL} cuando habilitamos el pull-up interno utilizamos la siguiente curva:

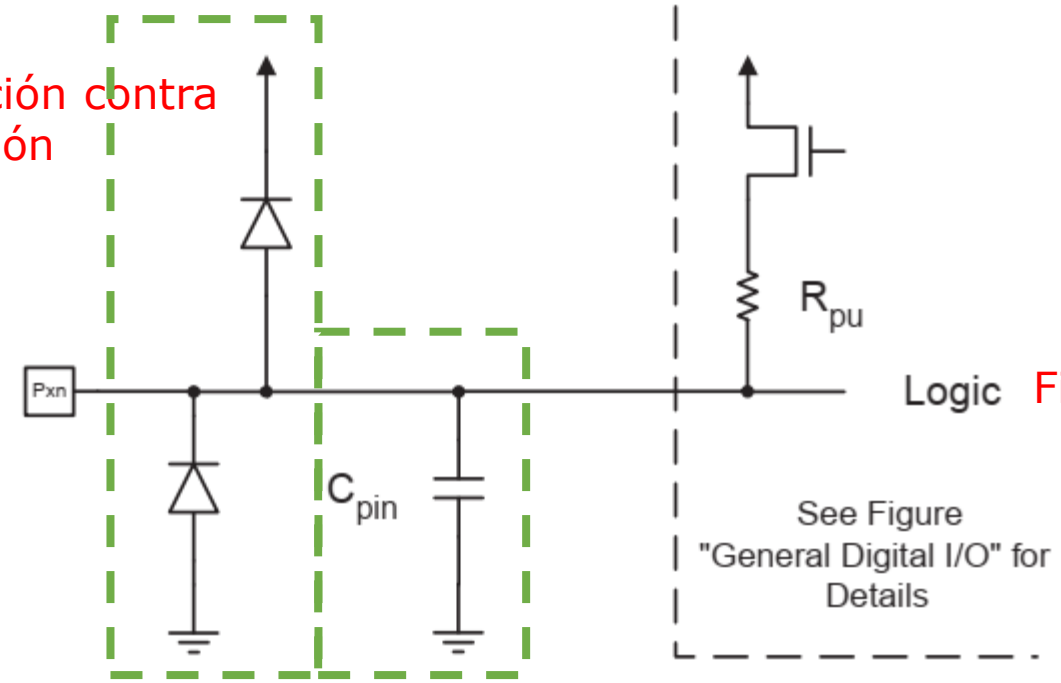
Figure 29-155. ATmega328P: I/O Pin Pull-up Resistor Current vs. Input Voltage (V_{CC} = 5 V)



Características eléctricas de entradas

- Otras especificaciones que podemos encontrar en las hojas de datos:

Figure 13-1. I/O Pin Equivalent Schematic



Diodos de protección contra sobretensión

Fig. pág 22

Capacidad de entrada
5pF valor típico

Bibliografía:

- *The AVR microcontroller & Embedded Systems*. Mazidi, Naimis. (CH8 y APENDICE C)

- *Los Microcontroladores AVR de ATMEL*. Felipe Espinoza (CH3 y CH8)

- Hoja de datos ATMEGA328P (características eléctricas)

PLC open source:

https://www.electroallweb.com/index.php/2019/12/14/plc-con-arduino-atmega-328p-v4/