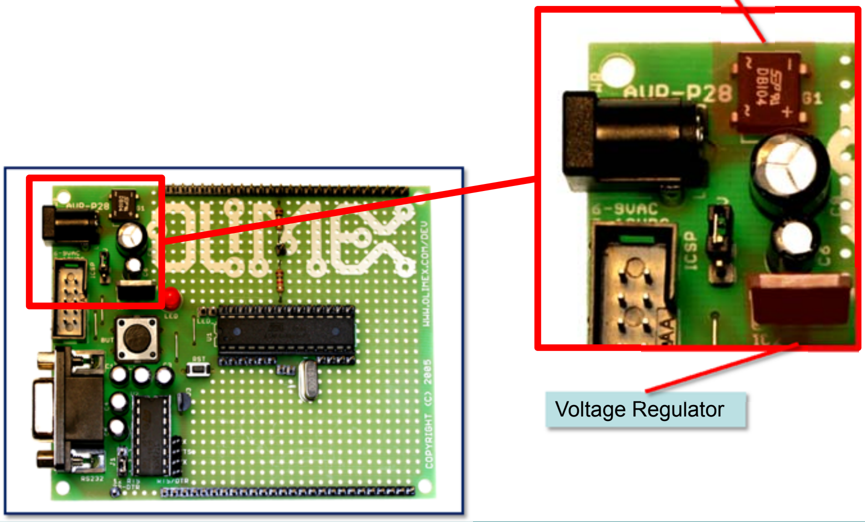
Embedded Systems

Some Hardware Considerations

Power Supplies

Power Supplies

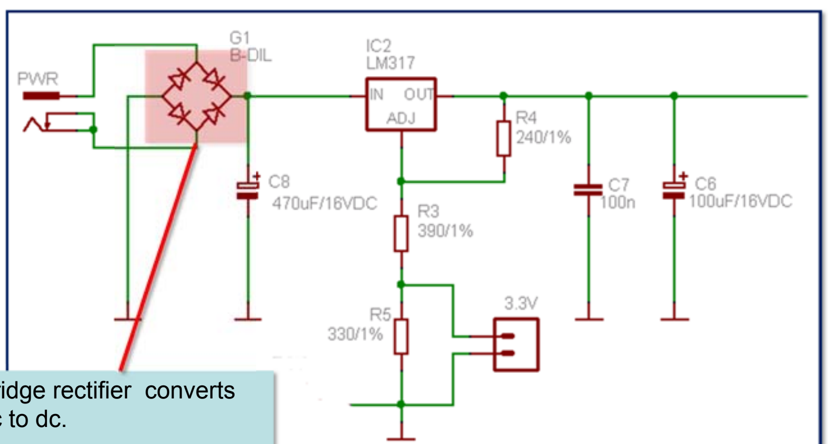
Bridge Rectifier



Voltage Regulator

Power Supplies

Power supply section from 28-pin development board

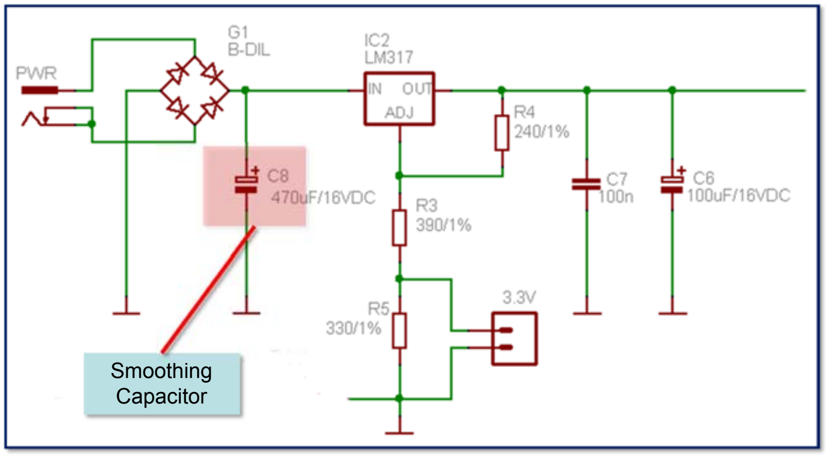


Bridge rectifier converts ac to dc.

Also allows us to use dc.

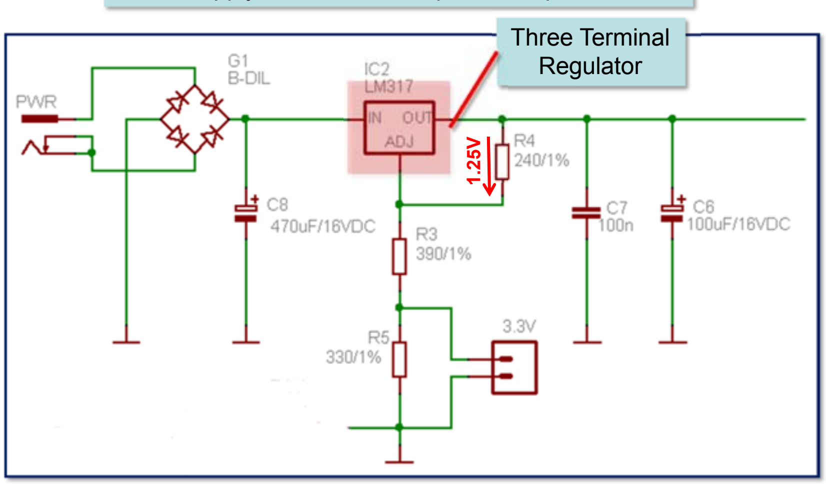
Power Supplies

Power supply section from 28-pin development board



Power Supplies

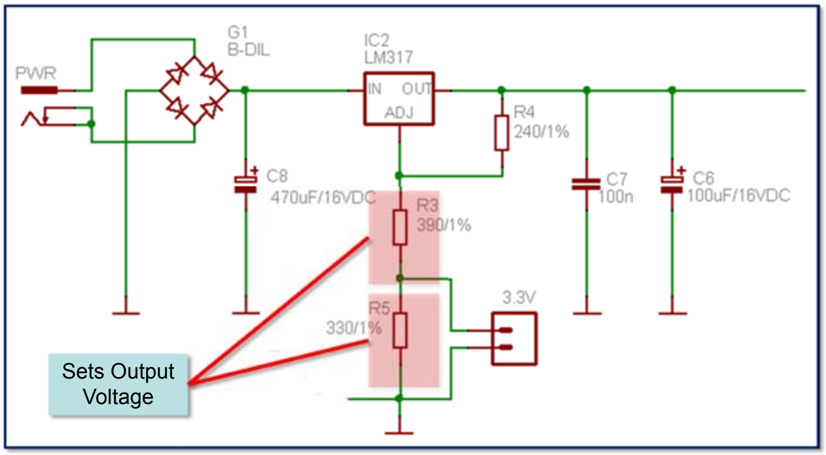
Power supply section from 28-pin development board



$I_{adj} \sim 50\mu A$

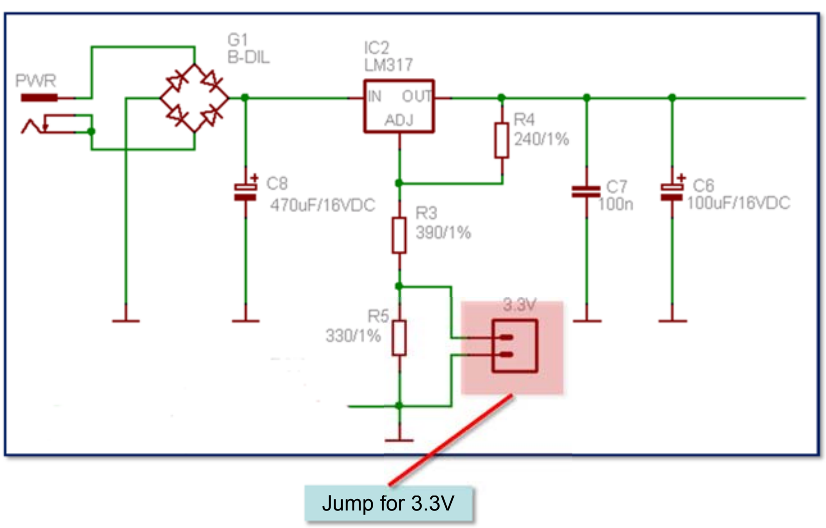
Power Supplies

Power supply section from 28-pin development board



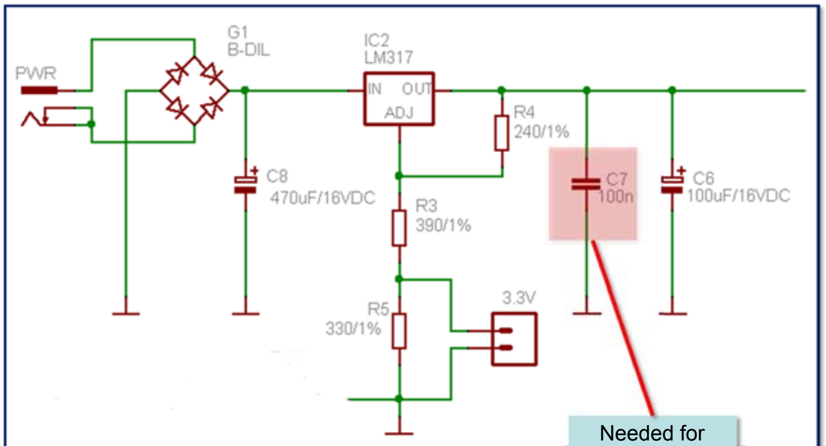
Power Supplies

Power supply section from 28-pin development board



Power Supplies

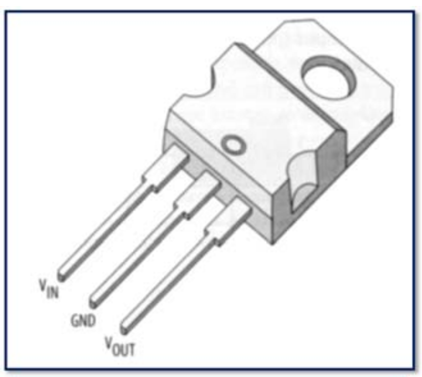
Power supply section from 28-pin development board



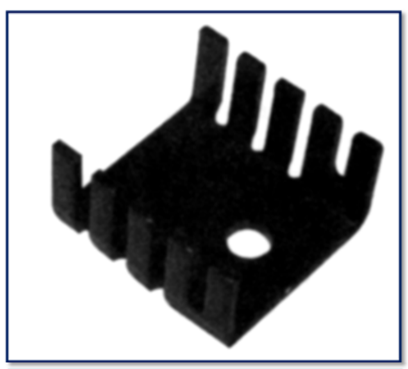
Needed for Stability

Power Supplies

Linear Three-Terminal Regulator



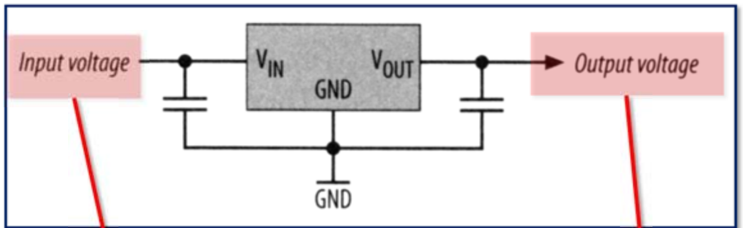
LM78XX Three-terminal regulator pinout in TO220 package



Heat sink to cool down regulator

Power Supplies

Linear Three-Terminal Regulator



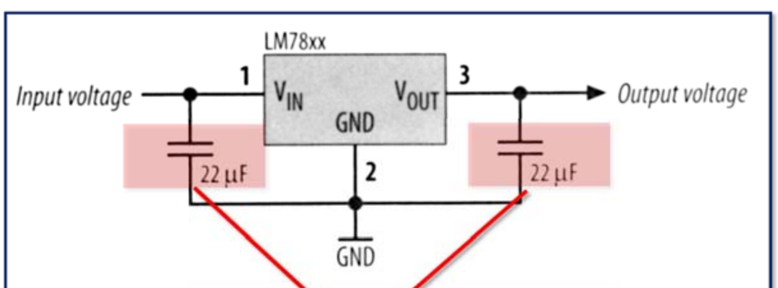
Varying input voltage, say 7-14 V. Must be larger than output voltage + some headroom, typically 1-2 V

Constant voltage: 3 V, 5 V, etc.

Note that linear regulators cannot step up a voltage, but can regulate it down.

Power Supplies

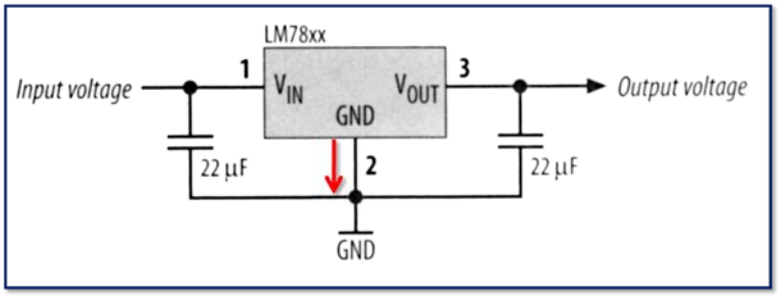
Linear Three-Terminal Regulator



These capacitors are easily-overlooked but a crucial for proper operation

Power Supplies

Linear Three-Terminal Regulator



Quiescent current for LM78xx regulators are large, and can waste lots of energy → not suitable for battery-operated equipment.

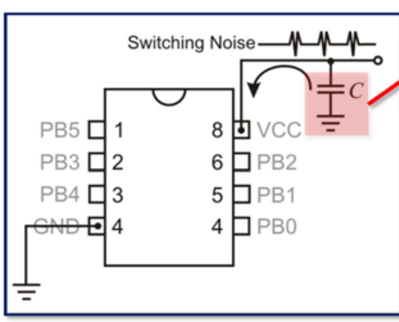
Decoupling Capacitors

Consider a microntroller that runs on a 10 MHz clock. This means the clock period is 100 ns. The rise and fall time of the clock is thus on the order of 10 ns or shorter.

The microcontroller's internal electronics (logic gates) create significant switching noise that appears on the power supply lines.

The current is drawn in very short spikes on the clock edges. If I/O lines are switching, the spikes will be even higher.

This kind of <u>current spike cannot be delivered over long power supply lines</u>; the main source is (or should be) the ***decoupling capacitor***.



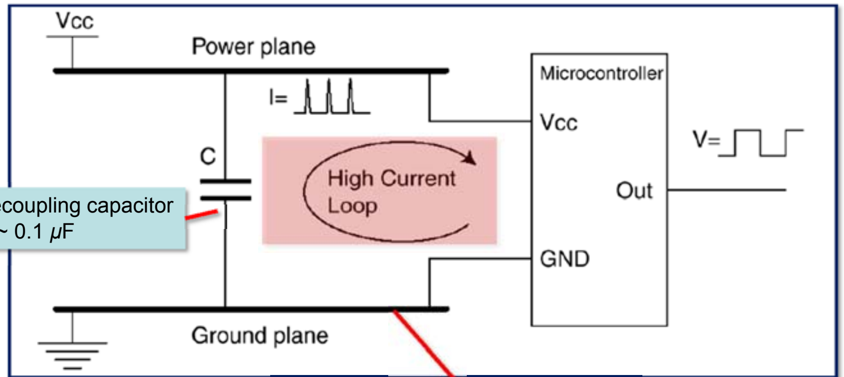
Decoupling capacitor ~ 0.1 μF

Used properly, a decoupling capacitor can greatly reduce switching noise.

Sometimes called a ***bypass capacitor***

Power Supply Decoupling

Wrong way to decouple power supply

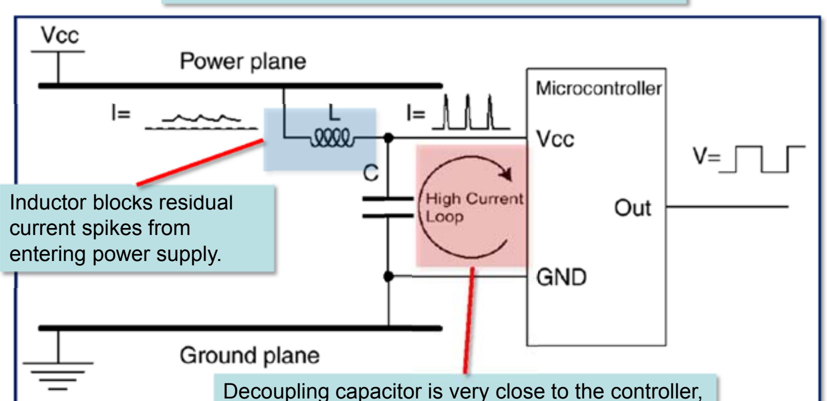


Decoupling capacitor is ~ 0.1 μF

Note: high loop current flows through the ground and can contaminate other circuits

Power Supply Decoupling

Better way to decouple power supply



Inductor blocks residual current spikes from entering power supply.

Decoupling capacitor is very close to the controller, across its GND and Vcc pins.

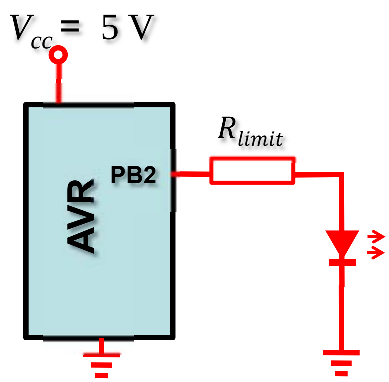
Large current spikes never flow through the circuit ground.

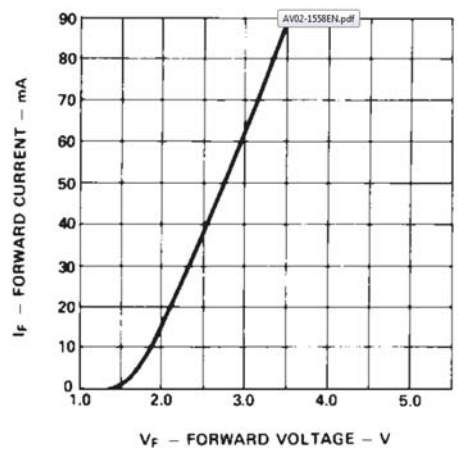
Controlling a (high power) load with a Microcontroller

Controlling high power loads with Microcontrollers

- **Often it is necessary to control (switch on & off) loads with a µC**
- **Examples are:**
  - Lamps or Power LEDs
  - Electro motors or stepper motors
  - Heating elements
  - Solenoids
  - GPS receiver
  - Etc.
- **µC output buffers have limits:**
  - ATmega88PA – Absolute Maximum Ratings:
    - DC current per I/O pin: 40 mA
    - DC current Vcc and GND pins: 200 mA
- **Requirements can exceed these limits**
  - E.g., motor with 300 mA @ 12 V, 120 Vac heating element, …
- **→ Use (power) transistors, relays (mechanical & solid state), etc.**

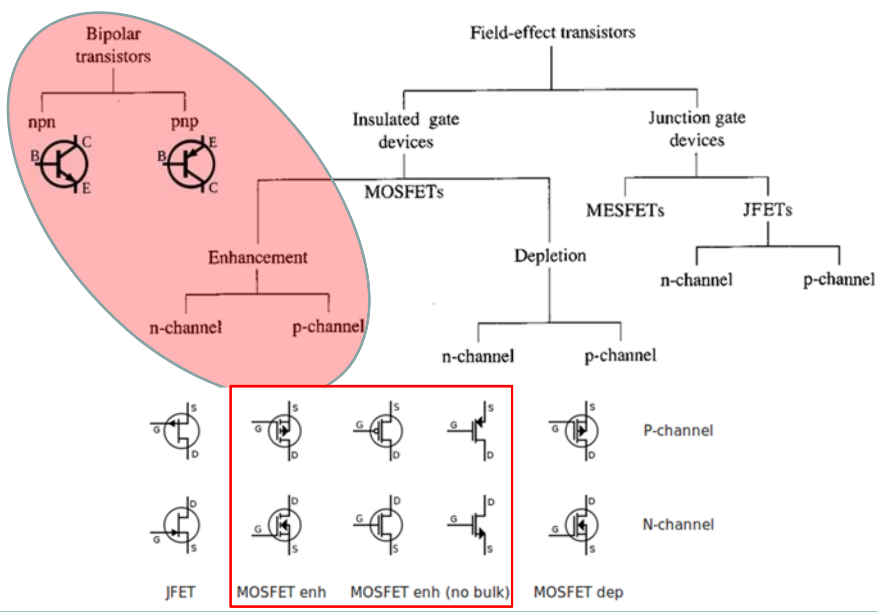
Driving an LED



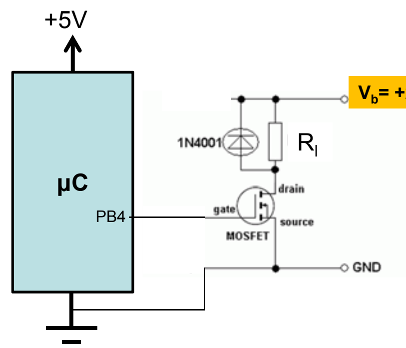


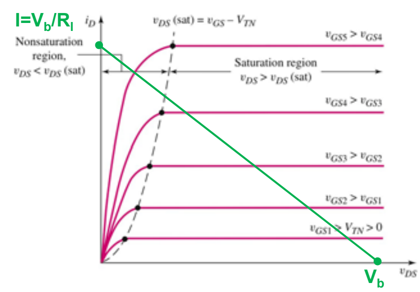
Use the LED's V-I characteristics from its datasheet to determine the forward voltage for a given current. Then apply Ohm's Law to determine R_{limit}

Overview - Transistors



Using a N-MOSFET (Enhancement) as Switch





MOSFET selection: make sure that V_{GSth} (V_{TN}) is suitable for logic levels!

Logic Level Power MOSFET

FAIRCHILD SEMICONDUCTOR®

RFP30N06LE, RF1S30N06LESM

Data Sheet January 2004

30A, 60V, ESD Rated, 0.047 Ohm, Logic Level N-Channel Power MOSFETs

These are N-Channel power MOSFETs manufactured using the MegaFET process. This process, which uses feature sizes approaching those of LSI integrated circuits gives optimum utilization of silicon, resulting in outstanding performance. They were designed for use in applications such as switching regulators, switching converters, motor drivers and relay drivers. These transistors can be operated directly from integrated circuits.

These transistors incorporate ESD protection and are designed to withstand 2kV (Human Body Model) of ESD.

Formerly developmental type TA49027.

Ordering Information

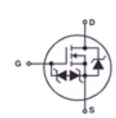
PART NUMBER	PACKAGE	BRAND
RFP30N06LE	TO-220AB	P30N06LE
RF1S30N06LESM	TO-263AB	1S30N06L

NOTE: When ordering use the entire part number. Add suffix, 9A, to obtain the TO-263 variant in tape and reel i.e. RF1S30N06LESM9A.

Features

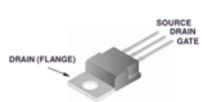
- 30A, 60V
- $r_{DS(ON)}$ = 0.047Ω
- 2kV ESD Protected
- Temperature Compensating PSPICE® Model
- Peak Current vs Pulse Width Curve
- UIS Rating Curve
- Related Literature
  - TB334 "Guidelines for Soldering Surface Mount Components to PC Boards"

Symbol

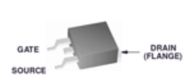


Packaging

JEDEC TO-220AB



JEDEC TO-263AB



Logic Level Power MOSFET

RFP30N06LE, RF1S30N06LESM

Absolute Maximum Ratings $T_A = 25^oC$, Unless Otherwise Specified

		RFP30N06LE, RF1S30N06LESM	UNITS
Drain to Source Voltage (Note 1)	V_{DSS}	60	V
Drain to Gate Voltage (R_{GS} = 20kΩ) (Note 1)	V_{DGR}	60	V
Gate to Source Voltage	V_{GS}	+10, -8	V
Continuous Drain Current	I_D	30	A
Pulsed Drain Current (Note 3)	I_{DM}	Refer to Peak Current Curve	
Pulsed Avalanche Rating	E_{AS}	Refer to UIS Curve	
Power Dissipation	P_D	96	W
Derate Above 25°C		0.645	W/°C
Electrostatic Discharge Rating, MIL-STD-883, Category B(2)	ESD	2	kV
Operating and Storage Temperature	T_J, T_{STG}	-55 to 175	°C
Maximum Temperature for Soldering			
Leads at 0.063in (1.6mm) from Case for 10s	T_L	300	°C
Package Body for 10s, See Techbrief 334	T_{pkg}	260	°C

CAUTION: Stresses above those listed in "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress only rating and operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.

NOTE:

1. T_J = 25°C to 150°C.

Electrical Specifications $T_C = 25^oC$, Unless Otherwise Specified

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Drain to Source Breakdown Voltage	BV_{DSS}	I_D = 250μA, V_{GS} = 0V, Figure 11	60	-	-	V
Gate to Threshold Voltage	$V_{GS(TH)}$	$V_{GS} = V_{DS}$, I_D = 250μA, Figure 10	1	-	2	V
Zero Gate Voltage Drain Current	I_{DSS}	V_{DS} = Rated B_{VDSS}, V_{GS} = 0	-	-	25	μA
		V_{DS} = 0.8 x Rated B_{VDSS}, V_{GS} = 0, T_C = 150°C	-	-	250	μA
Gate to Source Leakage Current	I_{GSS}	V_{GS} = +10, -8V	-	-	±10	μA
Drain to Source On Resistance (Note 2)	$r_{DS(ON)}$	I_D = 30A, V_{GS} = 5V, Figure 9	-	-	0.047	Ω
Turn-On Time	t_{ON}	V_{DD} = 30V, I_D = 30A, R_L = 1Ω, V_{GS} = 5V, R_{GS} = 2.5Ω, Figures 13, 16, 17	-	-	140	ns
Turn-On Delay Time	$t_{d(ON)}$		-	11	-	ns
Rise Time	t_r		-	88	-	ns
Turn-Off Delay Time	$t_{d(OFF)}$		-	30	-	ns
Fall Time	t_f		-	40	-	ns
Turn-Off Time	t_{OFF}		-	-	100	ns

Driving a (Stepper) Motor

- **To control the rotational direction of an electro motor, a drive circuit with bidirectional drive current capability is needed**
  - **→This can be accomplished by using a motor driver IC (H-bridge)**

TEXAS INSTRUMENTS

L293, L293D

SLRS008D – SEPTEMBER 1986 – REVISED JANUARY 2016

L293x Quadruple Half-H Drivers

1 Features

- Wide Supply-Voltage Range: 4.5 V to 36 V
- Separate Input-Logic Supply
- Internal ESD Protection
- High-Noise-Immunity Inputs
- Output Current 1 A Per Channel (600 mA for L293D)
- Peak Output Current 2 A Per Channel (1.2 A for L293D)
- Output Clamp Diodes for Inductive Transient Suppression (L293D)

2 Applications

- Stepper Motor Drivers
- DC Motor Drivers
- Latching Relay Drivers

3 Description

The L293 and L293D devices are quadruple high-current half-H drivers. The L293 is designed to provide bidirectional drive currents of up to 1 A at voltages from 4.5 V to 36 V. The L293D is designed to provide bidirectional drive currents of up to 600-mA at voltages from 4.5 V to 36 V. Both devices are designed to drive inductive loads such as relays, solenoids, DC and bipolar stepping motors, as well as other high-current/high-voltage loads in positive-supply applications.

Each output is a complete totem-pole drive circuit, with a Darlington transistor sink and a pseudo-Darlington source. Drivers are enabled in pairs, with drivers 1 and 2 enabled by 1,2EN and drivers 3 and 4 enabled by 3,4EN.

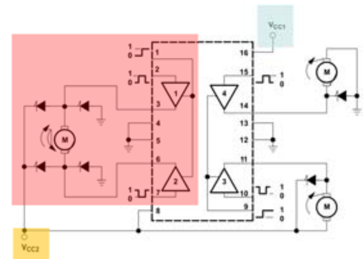
The L293 and L293D are characterized for operation from 0°C to 70°C.

Device Information[1]

PART NUMBER	PACKAGE	BODY SIZE (NOM)
L293NE	PDIP (16)	19.80 mm × 6.35 mm
L293DNE	PDIP (16)	19.80 mm × 6.35 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

Logic voltage: 4.5 – 7 V

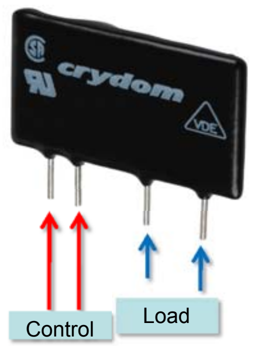


V_{CC1} – 36 V

Driving a High Power Load

Solid State Relay (SSR)

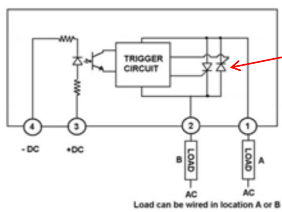
- SSR: up to 660 Vac; up to ~75 A
- DC (and AC) control



Description	CX240Dx
Nominal Voltage	5 VDC
Control Voltage Range	3-15 VDC
Minimum Turn-On Voltage	3.0 VDC
Drop Out Voltage	1.0 VDC
Typical Input Current	15 mAdc
Nominal Input Impedance	300 Ohm
Maximum Turn-On Time [msec] (3)	1/2 Cycle
Maximum Turn-Off Time [msec]	1/2 Cycle

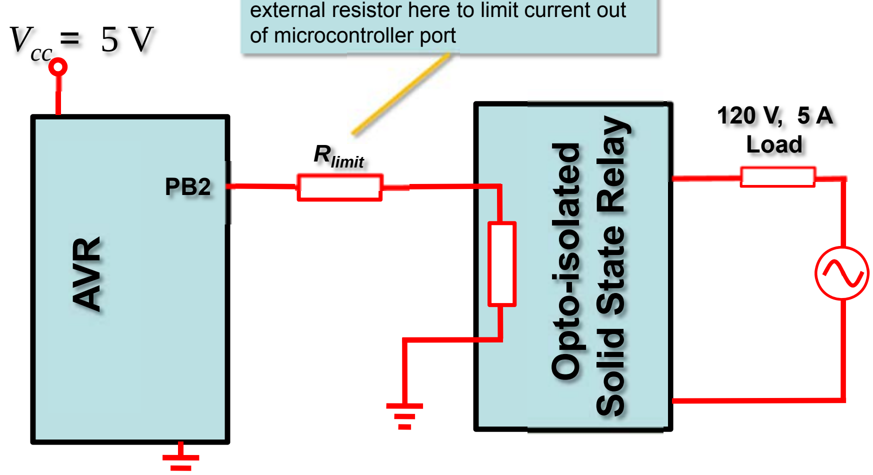
GENERAL SPECIFICATIONS

Thyristor



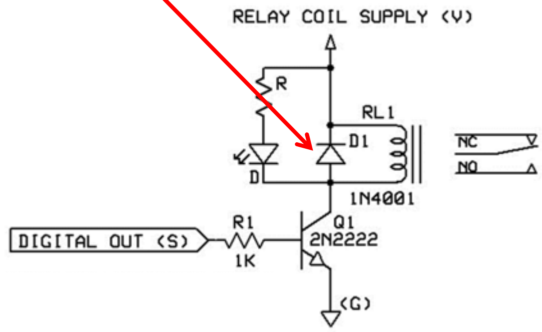
Driving a High-Power External Load

Depending on the SSR, one may need an external resistor here to limit current out of microcontroller port



Bipolar Transistors & Relay

Flyback Diode; prevents voltage spike, if transistor is turned off



"Safe" Approach for Switching a 120 Vac Load

- **Enclosed Power Relay (IoT Relay)**
- **Control voltage range: 3 – 48 V**
- **Load: 120 Vac and up to 12 A**
- **Price: ~ $ 24**
- **Good approach for use in labs!**

Miscellaneous Topics

Unconnected Pins

If some pins are unused, it is recommended to ensure that these pins have a defined level.

Even though most of the digital inputs are disabled in "deep sleep" modes, floating inputs should be avoided to reduce current consumption in all other modes where the digital inputs are enabled (Reset, Active mode and Idle mode).

The simplest method to ensure a defined level of an unused pin is to enable the internal pull-up.

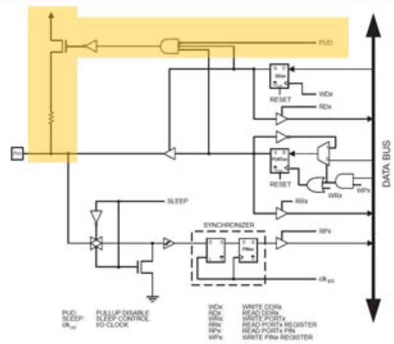
Connecting unused pins directly to VCC or GND is **not** recommended, since this may cause excessive currents if the pin is accidentally configured as an output.

Pull-Ups Revisited

The Pull-up Disable – PUD bit in MCUCR disables the pull-up function for all pins in all ports when set.

If PORTxn is written logic one when the pin is configured as an input pin, the pull-up resistor is activated.

To switch the pull-up resistor off, PORTxn has to be written logic zero or the pin has to be configured as an output pin.



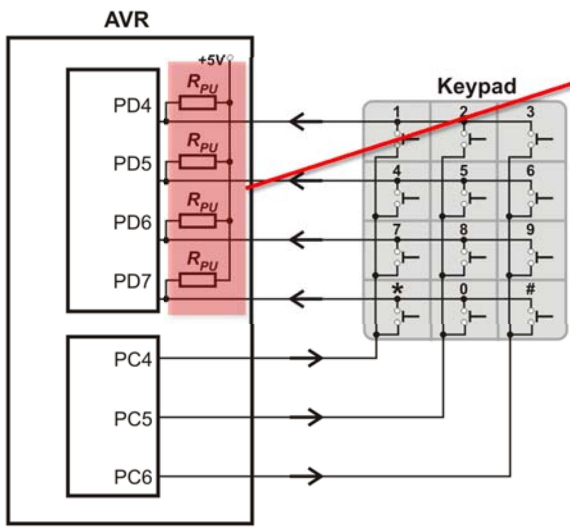
Pull-Ups Revisited

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

Symbol	Parameter	Condition	Min.	Typ.	Max.	Units
R_{RST}	Reset Pull-up Resistor		30		60	kΩ
R_{PU}	I/O Pin Pull-up Resistor		20		50	kΩ
V_{ACIO}	Analog Comparator Input Offset Voltage	V_{CC} = 5V V_{in} = V_{CC}/2		<10	40	mV
I_{ACLK}	Analog Comparator Input Leakage Current	V_{CC} = 5V V_{in} = V_{CC}/2	-50		50	nA
t_{ACID}	Analog Comparator Propagation Delay	V_{CC} = 2.7V V_{CC} = 4.0V		750 500		ns

Pull-up resistors can have a significant spread between parts, and even individual pins on a port, so beware…

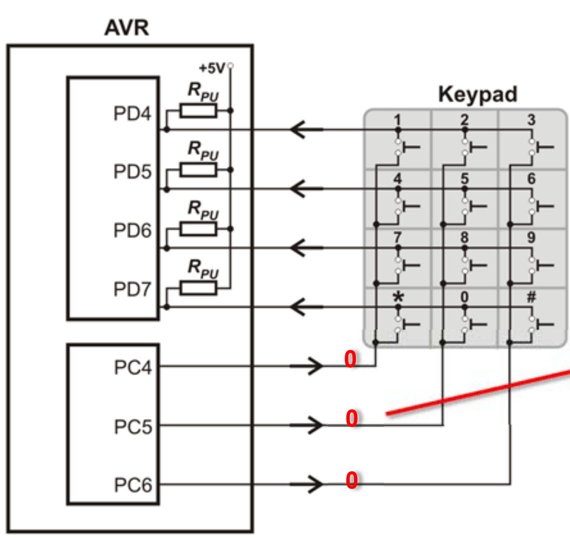
Reading a Simple (3×4) Keypad



Note the weak pull-ups on PD4-PD7.

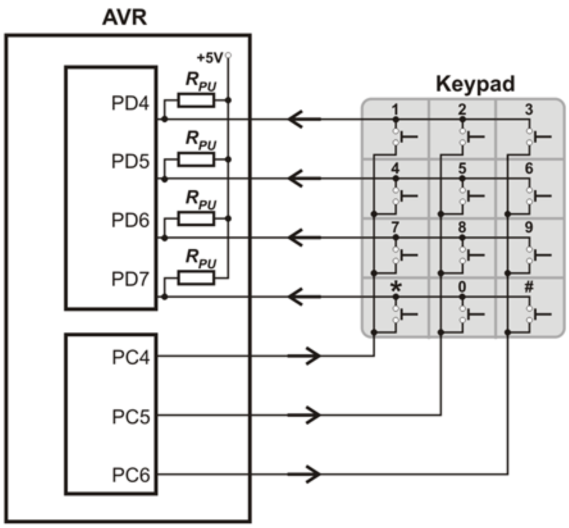
These must be enabled in software

Reading a Simple (3×4) Keypad



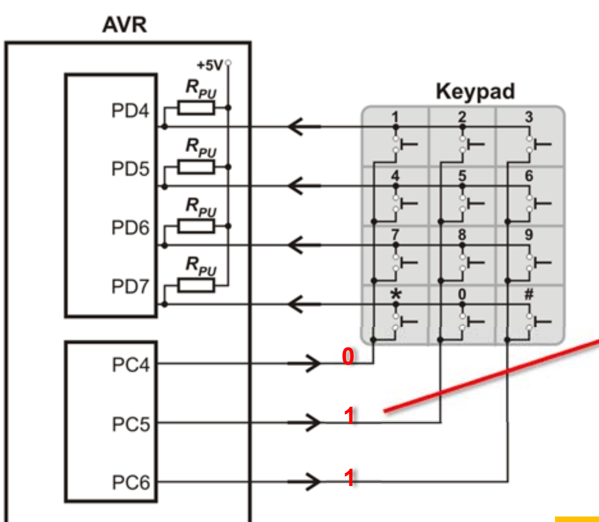
Step 1: Detecting a key press
- a) Drive PC4, PC5, PC6 low.
- b) READ Port D and look for zero on any of PD4-PD7
- c) If so, a key has been pressed

Reading a Simple (3×4) Keypad



Step 2: Debounce. Wait an appropriate period for the key switch to stabilize (10 ms is probably a good waiting time)

Reading a Simple (3×4) Keypad



Step 3: Search for the pressed key

a) Drive PC4 Low, PC5,PC6 High

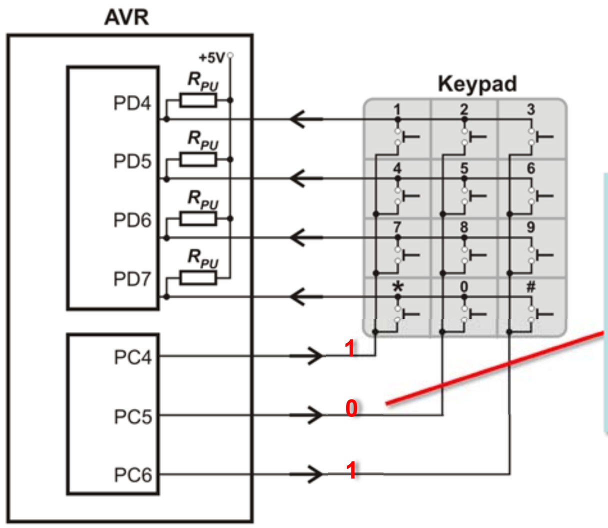
b) Read Port D

- PD4 = 0 → “1” pressed
- PD5 = 0 → “4” pressed
- PD6 = 0 → “7” pressed
- PD7 = 0 → “*” pressed

c) If pressed key is not found in column 1, repeat the process as necessary for the other two columns

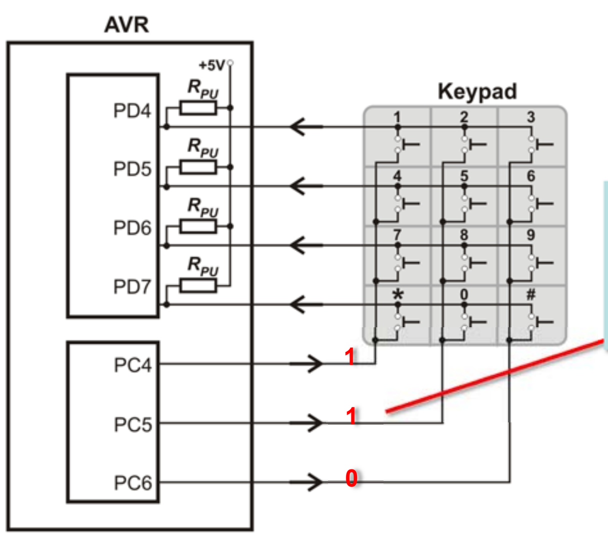
Q: What could go wrong?

Reading a Simple (3×4) Keypad



Step 4: Search for the pressed key
- a) Drive PC5 Low, PC4,PC6 High
- b) Read Port D
  - PD4 = 0 → "2" pressed
  - PD5 = 0 → "5" pressed
  - PD6 = 0 → "8" pressed
  - PD7 = 0 → "0" pressed
- c) If pressed key is not found in column 2, repeat the process as necessary for the other two columns

Reading a Simple (3×4) Keypad



Step 5: Search for the pressed key
- a) Drive PC6 Low, PC4,PC5 High
- b) Read Port D
  - PD4 = 0 → "3" pressed
  - PD5 = 0 → "6" pressed
  - PD6 = 0 → "9" pressed
  - PD7 = 0 → "#" pressed

… EOL