University of British Columbia
Electrical and Computer Engineering
ELEC291/ELEC292

Project 2: Metal Detecting Robot.

Dr. Jesús Calviño-Fraga P.Eng.
Department of Electrical and Computer Engineering, UBC
Office: KAIS 3024
E-mail: jesusc@ece.ubc.ca
Phone: (604)-827-5387

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Project 2 Description

Requirements

- Two micro-controller systems: must be different 'families'!
- Programmed in C.
- Both Robot and Remote must be battery powered.
- Discrete MOSFET drivers.
- Metal detector.
- Remote must have display, speaker, and joystick or equivalent.
- Radio Communication using JDY-40 or similar.
- Robot must move smoothly and in a well controlled manner (no jittering, no jumps).

Project 2 Description

Getting Started with a New Microcontroller System

1. Obtain/assemble the hardware. Also documentation: datasheets & manuals.

2. Obtain/install the development environment. Also documentation like manuals.

3. Obtain/install a means of putting the 'firmware' in the hardware. May require additional hardware tools and software.

4. Settle a workflow. Also: examples, application notes, and forums.

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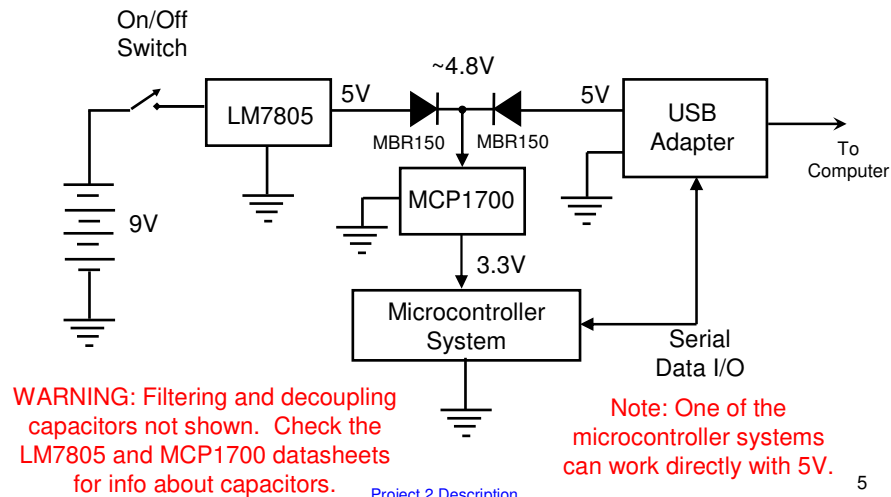# Getting Started with a New Microcontroller System

- In this course is not too difficult. Instructions provided for:
  - STM32L051: LQFP32. 64k flash. Microchip. ARM architecture.
  - LPC824: TSOP 20. 32k flash. NXP. ARM architecture.
  - PIC32MX130: DIP-28. 64k flash. Microchip. MIPS architecture.
  - ATmega328p: DIP-28. 32k flash. Atmel/Microchip. AVR architecture.
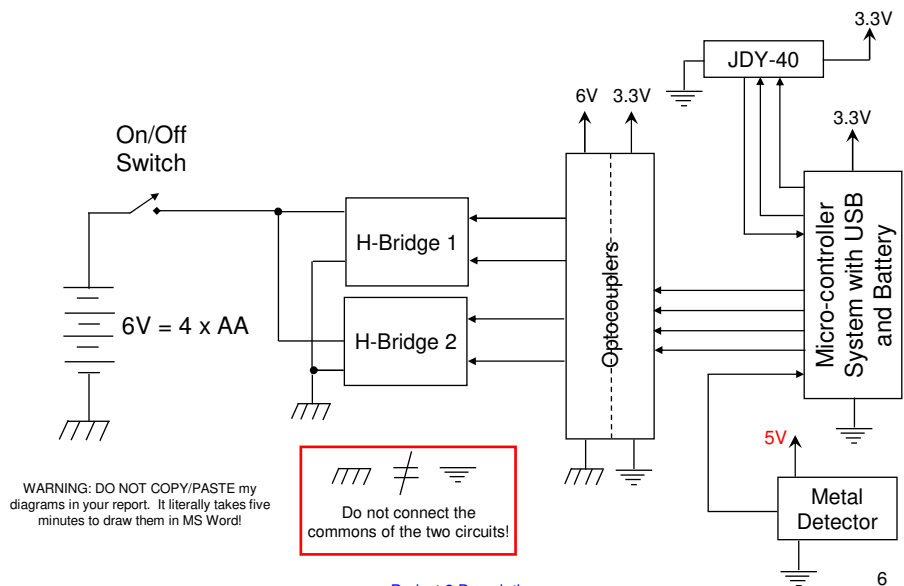 - MSP430G2553. DIP-20. 16k flash. Texas Instruments. MSP430 architecture.

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Micro-controller System with USB and 9V Battery

On/Off Switch

LM7805 — 5V — ►|— MBR150 — ~4.8V — |◄— MBR150 — 5V — USB Adapter → To Computer

9V

MCP1700

3.3V

Microcontroller System

Serial Data I/O

WARNING: Filtering and decoupling capacitors not shown. Check the LM7805 and MCP1700 datasheets for info about capacitors.

Note: One of the microcontroller systems can work directly with 5V.

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ROBOT block diagram

3.3V

JDY-40

3.3V

6V 3.3V

On/Off Switch

6V = 4 x AA

H-Bridge 1

H-Bridge 2

Optocouplers

Micro-controller System with USB and Battery

5V

Metal Detector

WARNING: DO NOT COPY/PASTE my diagrams in your report. It literally takes five minutes to draw them in MS Word!

Do not connect the commons of the two circuits!

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Important Considerations for the Robot Micro-controller

- Make sure you have available (at a bare minimum) and know how to use at the same time in the ROBOT micro-controller system:
  - 4 digital outputs to control the motors using PWM (4 pins)
  - Extra TXD/RXD and SET pins for JDY-40 (3 pins)
  - 1 digital input for the metal detector (1 pin)
- I think all the processors provided meet the minimum requirements

Remote block diagram

Important Considerations for the REMOTE Micro-controller.

- Make sure you have available (at a bare minimum) and know how to use at the same time in the REMOTE micro-controller system:
  - 6 digital outputs for LCD (6 pins)
  - Extra TXD/RXD and SET pins for JDY-40 (3 pins)
  - 2 analog inputs for Joystick (2 pins)
  - 1 output for the speaker (1 pin)
- I think all the processors provided meet the minimum requirements

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Basic Metal Detector: Colpitts Oscillator.

Tip: To save space make your own CMOS inverter! (Use 5V. 3.3V may not work because of large Vt of PMOSFET)

R

C₁ L C₂
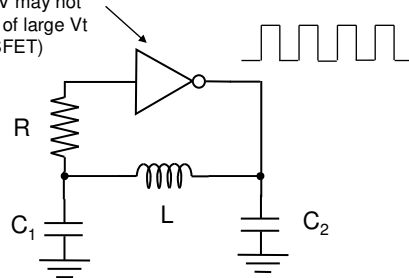
$$C_T = \frac{C_1 C_2}{C_1 + C_2}$$

$$f = \frac{1}{2\pi\sqrt{LC_T}}$$

R=100Ω to 1kΩ

C₁=1nF to 10nF

C₂=10nF to 100nF

L=1mH

If you place metal close to the inductor, it will change the magnetic field, slightly changing the inductance which is reflected as a change in the oscillator frequency.

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Colpitts Oscillator with Discrete CMOS Inverter
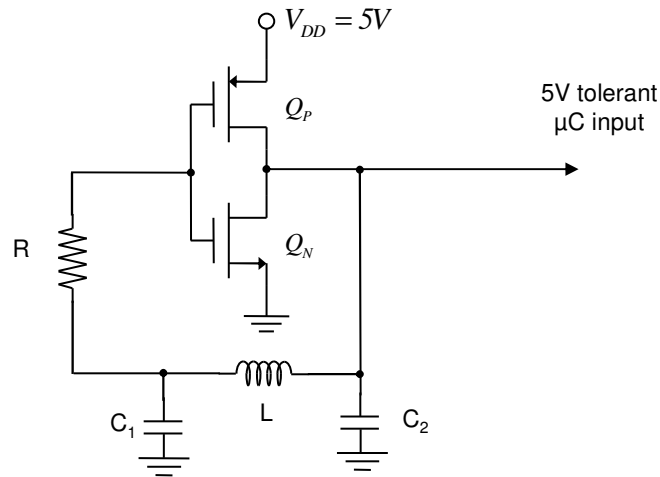
$V_{DD} = 5V$

Q_P

5V tolerant
µC input

R

Q_N

C_1 L C_2

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Metal Detector Inductor

- Use the magnet wire and the old wheel design in your project #2 kit to make the metal detector inductor; instructions posted on Canvas:
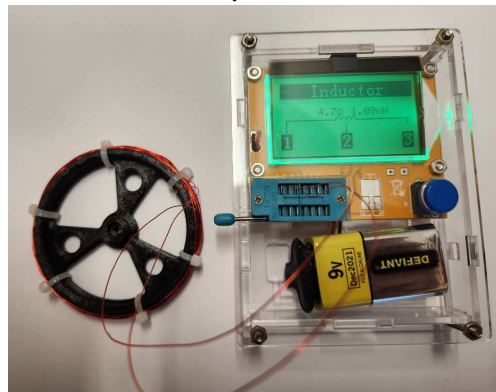
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Robot Construction

Part #	Description
Solarbotics GM4	Gear Motor 4 - Clear Servo
	3D printed wheels (two)
Tamiya 70144	Ball Caster
4 x AA	Battery holder
1 x 9V cable	9V battery clip
	Aluminum chassis made using the water jet cutter.

Robot Construction

- Instruction posted in Canvas:
  - How to assemble the complete robot.
  - How to make the metal detector inductor.
- You'll need to figure out the electronics and software yourself (as a team!).
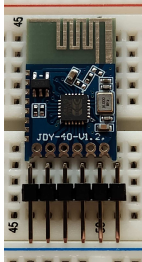
Robot (without electronics)
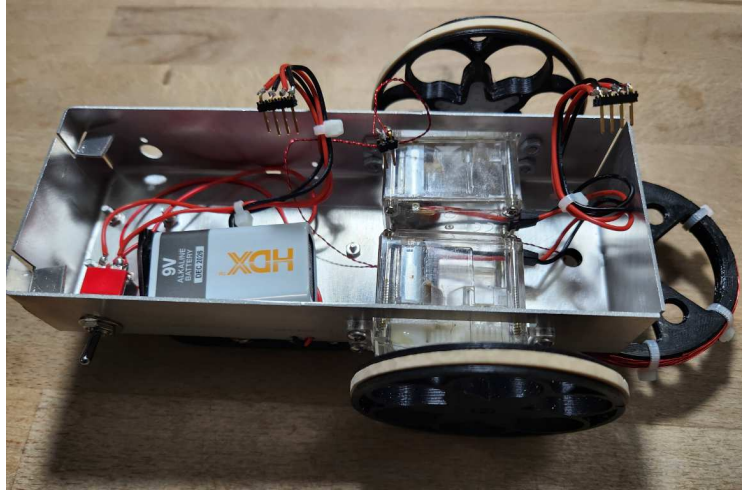
JDY-40 Radio

- Needs three pins: TXD, RXD, and SET.
- Use at low baud rates. 9600 baud top.
- Power ONLY with 3.3V. Be super careful with voltage polarity.
- Set an unique device ID to your JDY-40 pair using this 'AT' command:

  `SendATCommand("AT+DVIDxxxx\r\n");`

  Where xxxx is 0000 to FFFF (in hex)
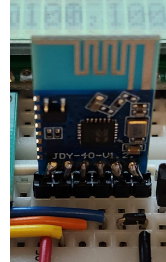- Example for the EFM8 provided on Canvas.

JDY-40 Radio Pins

PROBLEM: JDY-40 pins are 2mm apart.
Bread board holes are 2.54mm apart.

Solution step 1: bend the header pins so that they match the JDY-40 holes spacing.
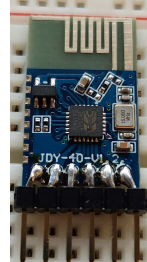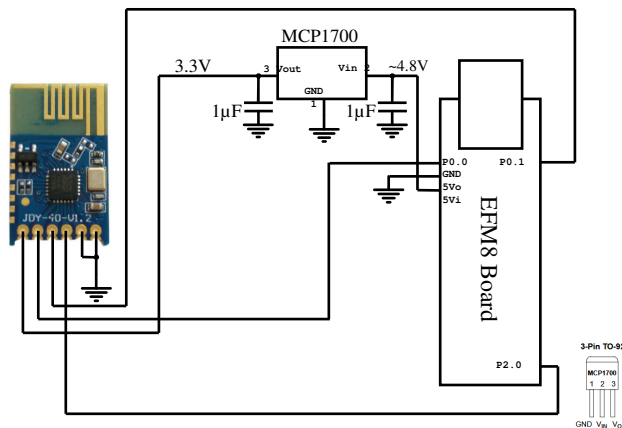
Solution step 2: Solder header on top.

Solution step 3: Plug board into bread board

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JDY-40 Radio Wiring: EFM8

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JDY-40 Radio Wiring: ATMega328P

All resistors 1kΩ

ATMega328P

- (16) PB2
- (15) PB1
- (6) PD4
- (5) PD3

MCP1700
3-Pin TO-92

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JDY-40 Radio Wiring: MSP430G2553/MSP430G2253
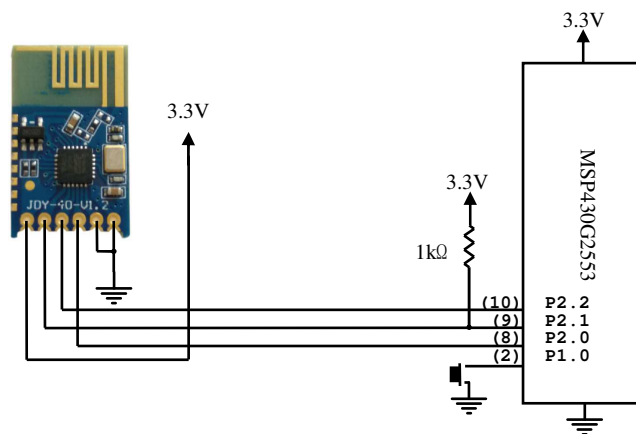
3.3V

3.3V

1kΩ

MSP430G2553

- (10) P2.2
- (9) P2.1
- (8) P2.0
- (2) P1.0

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JDY-40 Radio Wiring: LPC824
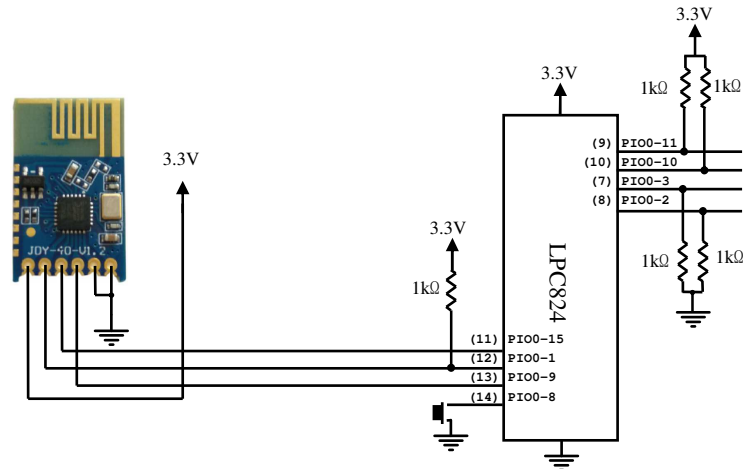
3.3V

1kΩ 1kΩ

3.3V

(9) PIO0-11
(10) PIO0-10
(7) PIO0-3
(8) PIO0-2

1kΩ 1kΩ

LPC824

3.3V

1kΩ

3.3V

(11) PIO0-15
(12) PIO0-1
(13) PIO0-9
(14) PIO0-8

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JDY-40 Radio Wiring: STM32L051
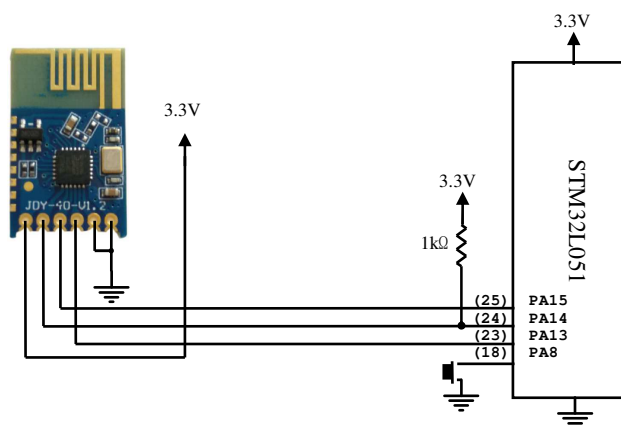
3.3V

STM32L051

3.3V

3.3V

1kΩ

(25) PA15
(24) PA14
(23) PA13
(18) PA8

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JDY-40 Radio Wiring: PIC32MX130
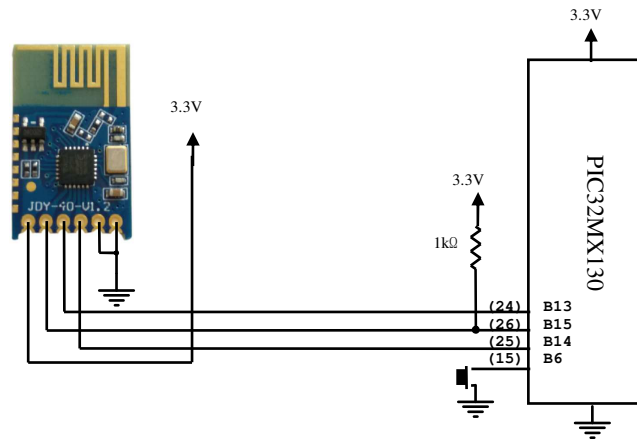
3.3V

3.3V

3.3V

1kΩ

PIC32MX130

(24) B13
(26) B15
(25) B14
(15) B6

23
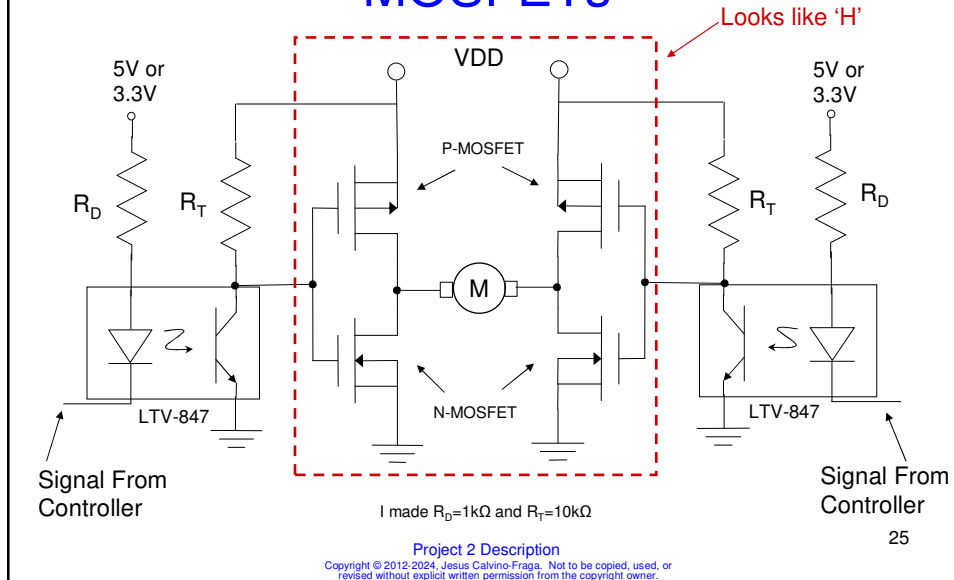

Communicating with the JDY-40

- Ideally the micro-controller connected to the JDY should have a dedicated <u>HARDWARE</u> UART (serial port).
- The two micro-controllers that don't have an extra UART are the ATMega328p and the MSP430G2553. One solution:
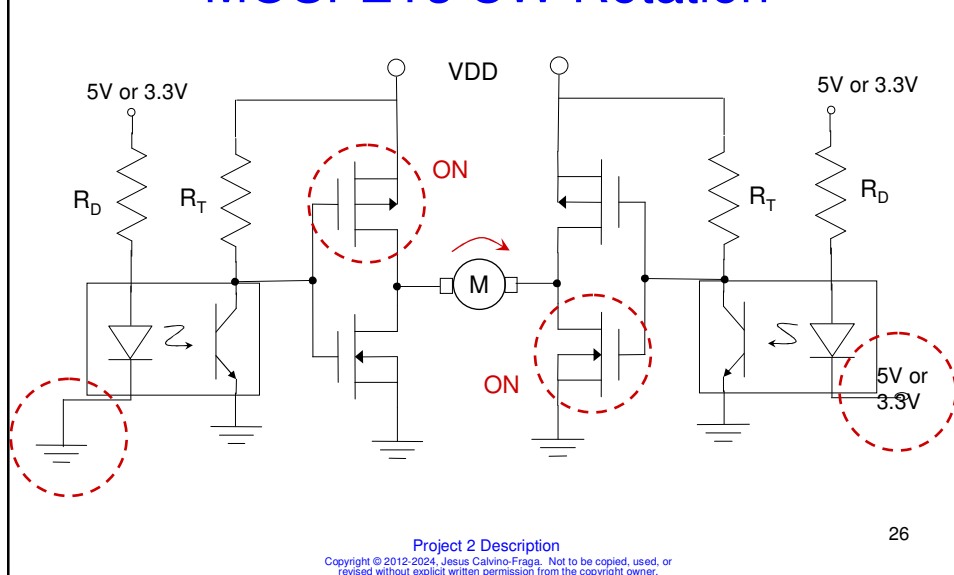 - Use a software UART. Interrupt driven if possible.
- Examples posted on Canvas.

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H-Bridge with Optocouplers and MOSFETs

Looks like 'H'

VDD

P-MOSFET

N-MOSFET

5V or 3.3V

R_D R_T

LTV-847

Signal From Controller

M

5V or 3.3V

R_T R_D

LTV-847

Signal From Controller

I made R_D=1kΩ and R_T=10kΩ

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H-Bridge with Optocouplers and MOSFETs CW Rotation

VDD

5V or 3.3V

R_D R_T

ON

M

ON

5V or 3.3V

R_T R_D

5V or 3.3V

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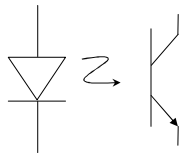# H-Bridge with Optocouplers and MOSFETs CCW Rotation
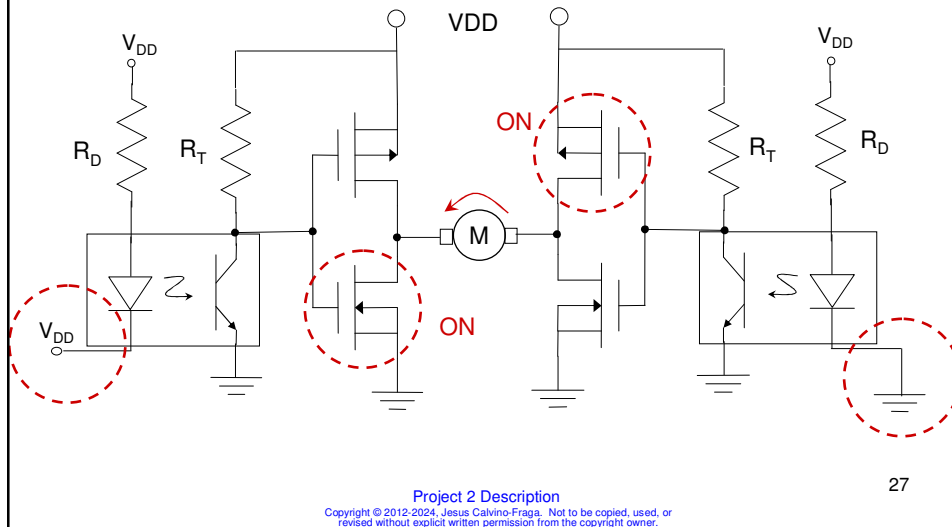
Optocouplers

- An optocoupler is a combination of a light source and a photosensitive element
- You can use an optocoupler when you want to isolate high or very high voltages, inductive circuits, or "noisy" circuits from the microcomputer system.
- The typical optocoupler consists of an infrared LED and a NPN BJT.
- The BJT usually doesn't have a base pin! Instead it is the light from the LED what is used to saturate the transistor.

Designing with Optocouplers

- When designing with optocouplers you take into consideration the following parameters:
  - The current transfer ratio (CTR) is a parameter similar to the DC current amplification ratio of a transistor (β) and is expressed as a percentage indicating the ratio of the output current (I_C) to the input current (I_F).
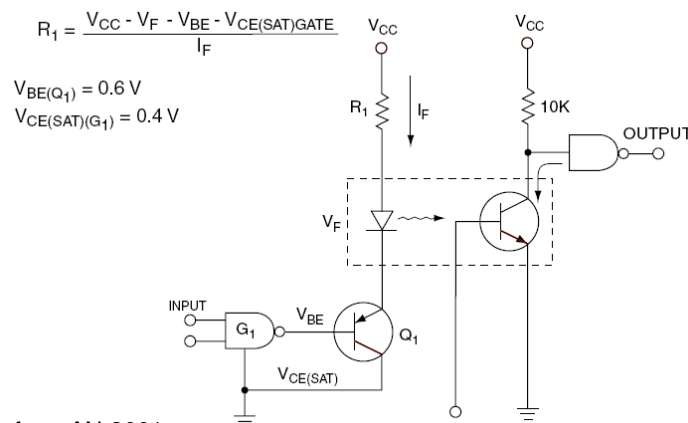 $CTR(\%)=(I_C/I_F) \times 100$
  - The Diode forward voltage (1.2 to 1.4V).
  - The maximum diode forward current (around 50mA max).
  - The BJT saturation voltage (0.1 to 0.4V).
  - The voltage isolation between the diode and the transistors (a few hundred volts to thousands of volts)

Some optocouplers include a base pin!

Project 2 Description

Optocouplers circuits

$$R_1 = \frac{V_{CC} - V_F - V_{BE} - V_{CE(SAT)GATE}}{I_F}$$

$$V_{BE(Q_1)} = 0.6 \text{ V}$$
$$V_{CE(SAT)(G_1)} = 0.4 \text{ V}$$

This is from AN-3001, Fairchild Semiconductors

Project 2 Description

LTV-846/LTV-847 Optocoupler

- CTR=50%
- Diode forward voltage=1.4 max.
- Maximum diode forward current is 50mA
- The BJT saturation voltage is less than 0.12V!
- Voltage isolation $5000V_{RMS}$

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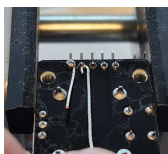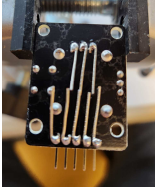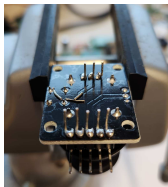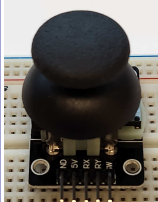
Why you may need Optocouplers?
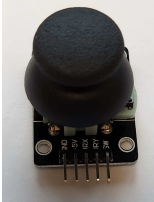
- To interface the low voltage of the microcontroller to the high voltage of the motors.
- To keep the 'noise' from the motors away from the microcontroller and the metal detector circuit.
- It could be possible to not use optocouplers this year... I hadn't tested that yet.

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Joystick

PROBLEM: The joystick can not be plugged in the breadboard.

Solution step 1: Make a little loop with hook-up wire and solder around the back of the connector pins.

Solution step 2: Add wires to the pins of the connector and the pins of one of the potentiometers as shown.

Solution step 3: Bend the wires perpendicular to the board. Cut so they are about 1cm long.

Solution step 4: Plug the joystick into the breadboard!

Project 2 Description

Robot Control and Movement
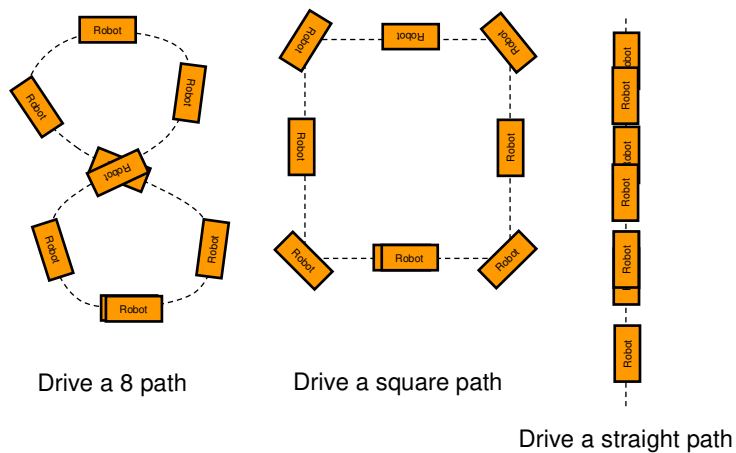
Drive a 8 path

Drive a square path

Drive a straight path

Project 2 Description

Battery powered.

- Both the robot and the remote must be battery powered.
- A 9 volt battery strap and a 4 x AA battery holder are included in the parts kit for this project.
- You can use any kind of batteries you want, provided that you acquire the batteries and the holders yourself.
- WARNING: batteries are neither included in the parts kits nor they will be provided in the lab. You must buy your own batteries.
- Brand name batteries have lower internal resistance and work better, but they are more expensive.

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Recommendations

- Keep the robot/remote wiring tidy and short.
- Keep all circuits as simple as you can.
- Do not use any of the [s]printf() or [s]scanf() functions. They are big and slow.
- Keep ISRs as minimal as possible.
- Transport robot and remote in a box.
- Do not short-circuit batteries.

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