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R.E.C.O.R.D.

(Reward-Cost in Rodent Decision-making)

Electronics build guide

Revision 1.1

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Overview

This assembly guide will instruct you in your creation of the electronic components of our custom arena behavioural apparatus. These components are made utilising basic wires, lights, and cables, to allow for a taylormade task to be used in the study of decision-making and disorders in rodents in a cost-effective and open-science friendly way. The customization of our system allows for on the fly changes and adaptations to the experimental environment and process, as well as animal behaviour. Further, it enables the interchangeability and replacement of parts as they wear down over the course of thousands of behavioural trials. In this guide you will find the parts and materials, dimensions and measurements, along with links and assembly instructions, to our custom electronic system as well as the code and programs that we are using to manipulate it.

LED assemblies and cable

CAUTION: You will be working with very hot equipment in this section. Please make sure you take the proper precautions to not burn yourself, other team members, or any objects inside and outside of your work area!

The LED assemblies on the arena signal a cost (associated with the food rewards) at each corner. Eacha arena will house four of these assemblies, mounted onto every feeder piece in the arena. Each assembly is made up of four LEDs connected in parallel and are controlled by a single data wire, with a single ground wire providing them ground. By the end of this section you should have 4 LED modules, each made up of 4 LEDs, with one red wire and one black wire coming out of the assembly.

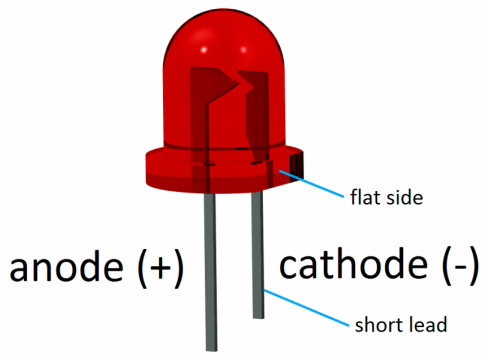
Materials

- *16 blue LEDs*
- *Black wire*
- *Red wire*
- *Dupont wire, female, red*
- *Dupont wire, female, black*
- *Two-conductor speaker wire*
- *Electrical tape*
- *soldering iron*
- *Solder*
- *Wire strippers*
- *Wire cutters*
- *Multimeter*

1. **LED Anatomy**

Every LED has two “legs”; one receives voltage from a source and the other completes the circuit by allowing the current to flow towards ground. These are called “**anode**” and “**cathode**”, respectively. The anode and cathode can be identified by observing the LED legs, the **anode** is the **longer leg** while the **cathode** is the **shorter leg**, see Figure 2.1 for reference.

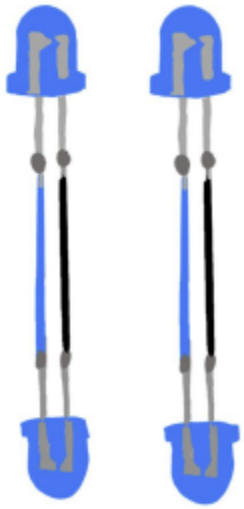
Figure 2.1. Identifying the cathode and anode:

	Figure 2.1 A: Illustration showcasing the anode vs cathode based length leg size.

2. Preparing the Wires

Using the wire cutters, measure and cut three *4 cm* segments of both **red and black wire**. Strip both ends of all wire segments using wire strippers, being careful not to cut the wire (or yourself) by accident.

3. Soldering Preparation



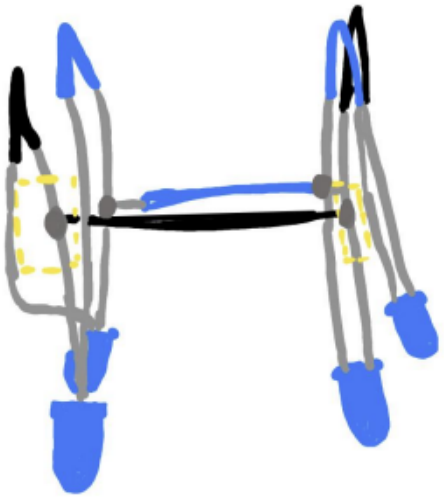
Make sure the soldering iron is resting in its holder and nothing is touching the metal tip at the end. The soldering iron will get *very hot very quickly!* It’s important to handle this device with care. Turn the soldering iron on and wait for it to heat up. *DO NOT HOLD THE SOLDERING IRON BY THE TIP, YOU WILL BURN YOURSELF. Always grab the soldering iron by its heat insulated padding.*

4. Assembling the LED ring part 1

The **cathode** will be colour coded **black** and the **anode** will be colour coded **red** on the LEDs. *It is extremely important that the LED is colour coded and soldered correctly in the next steps or else the LED may not light up!*

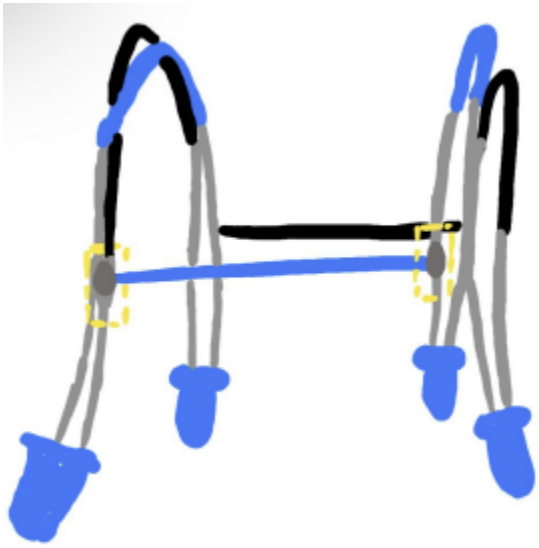
Connect two LEDs together by soldering their cathodes together with a black wire segment and their anodes with a red wire segment. Repeat this step twice to end up with two two-LED circuits.

5. **Assembling The LED Ring part 2**



Use the remaining black wire segment to bridge the cathodes of the two LED pairs together. Then, using the red wire segment, bridge the anodes of the same two LEDs or of the other two LEDs. This will result in either a U-shaped or O-shaped LED circuit where all four LEDs are connected in parallel.

6. **Adding a connector to the LED assembly**



To make the LED rings detachable (and thus replaceable), a connector is needed. Create a new set of red and black wires with a female dupont connector on one end, and a stripped end. Solder the stripped end of the red connector wire to the anode of one of the LEDs in the assembly, and the black connector wire to the cathode of another LED in the assembly.

For a U-shaped arrangement, we recommend soldering the connector wires to the two free-hanging LEDs. For the O-shaped arrangement, the connector wires can be soldered to any two adjacent LEDs.

Repeat steps 2 through 6 to create three more LED assemblies for one RECORD arena.

7. **Preparing for the LED cable**

Cut four long segments of two-conductor copper speaker cable and strip about 1 cm of the inside black and red wires at both ends. The segments should be long enough to put some amount of distance between the RECORD electronics and the RECORD arena. It is recommended that this distance is measured beforehand and to add about 1 metre to it for slack.

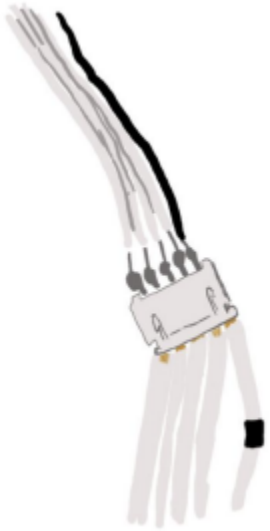
8. **Creating the JST connector end of the cable**

On one end of the four cables, twist and solder the four black wires together, then solder an additional wire to the end of this joint.

Create five wires with a JST connector pin on one end and strip the other end.

Solder the red speaker wires to four of these wires and insert them into pins 1 through 4 of the JST-XH connector housing.
Solder the black speaker wire bundle to the last connector wire and insert it into pin 6 of the JST-XH connector housing.

Put this end of the wire aside for now.



9. **Creating the LED assembly connector**

   On the other end, a male dupont connection for an LED assembly must be made for each cable. Solder a red male dupont wire to the red speaker wire and a black male dupont wire to the black speaker wire. Wrap any exposed solder joints with electrical tape.

10. **Testing connection continuity**

    Connect the LED assemblies to the dupont connector end of the completed LED cable. Use the multimeter to test continuity between the connected LED terminals and each pin of the JST-XH connector. Keep track of which cable corresponds to which LED assembly and label the wire and LEDs appropriately.

Valves and valve cables

CAUTION: You will be working with very hot equipment in this section. Please make sure you take the proper precautions to not burn yourself, other team members, or any objects inside and outside of your work area!

The solenoid valves are involved in reward (food) delivery to the animal in the arena. These valves are driven by 20 - 25 Volts direct current (DC) which will be delivered by an external power source. By the end of this section, you should have a set of four valves and a valve cable with a 6-position female JST-XH connector.

Materials

- *4 Solenoid Valves*
- *Speaker cable*
- *1 Six-position female JST-XH connector*
- *Dupont wire (female)*

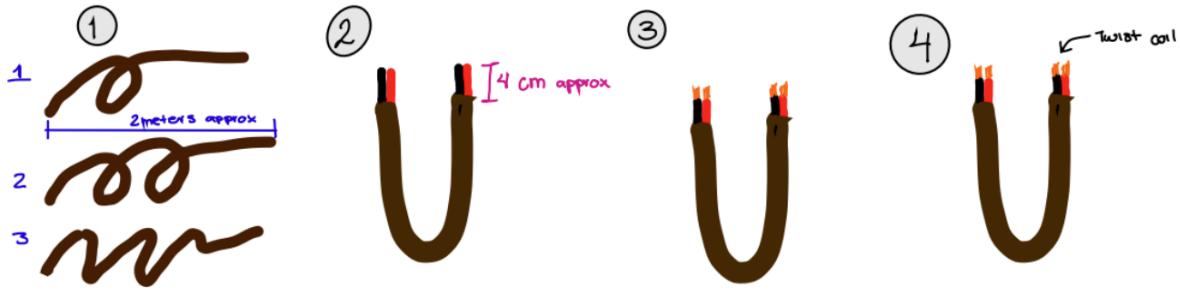
- *Dupont wire (male)*
- *A soldering iron*
- *Solder*
- *Wire strippers*
- *Wire cutters*
- *And a Multimeter*

1. **Preparing the cable**

   Using the wire cutters, measure and cut a section of **speaker cable** for each valve, to end up with 4 segments of speaker cable. The segments should be long enough to put some amount of distance between the RECORD electronics and the RECORD arena. It is recommended that this distance is measured beforehand and to add about 1 metre to it for slack.

   Strip both ends of the speaker wire. One end will need female dupont connectors and the other will be housed by a 5-pin JST-XH connector.

   Prepare 4 wires with one female dupont connector each, 8 with a male dupont connector, and 5 with an XH pin on one end. The other end of each of these wires should be stripped and prepared for soldering.



2. **Soldering Preparation**

   Make sure the soldering iron is resting in its holder and nothing is touching the metal tip at the end. The soldering iron will get *very hot very quickly!* It's important to handle this device with care. Turn the soldering iron on and wait for it to heat up. *DO NOT HOLD THE SOLDERING IRON BY THE TIP, YOU WILL BURN YOURSELF. Always grab the soldering iron by its* ***heat insulated padding.***

3. **Soldering connector wires to the valve**

   Each valve has three terminals, two on the top and one on the bottom. Solder the stripped end of two male dupont connector wires to one each one of the top terminals. Because the valves are not polarised, colour coding is not required.

4. **Creating the connector on the wire**

As with the LED cables, twist the four internal black wires on one end of the stripped speaker wire and solder them together, then solder a wire with an XH pin to the end of this joint. Then, solder one wire with an XH pin to each of the internal red wires on the same end of the speaker cable. All valves will be sharing one ground through one terminal, and will be supplied with power through the other terminal.

On the other end of the cable, solder a female dupont connector wire to each of the internal speaker wires.

Lastly, introduce the five XH pin wires into the JST-XT housing. Pin 5 will house the 4-wire joint wire and pins 1 through 4 will house the remaining wires.

5. **Testing connection continuity**

   Connect the valves to the dupont connector end of the completed valve cable. Use the multimeter to test continuity between the connected valve terminals and each pin of the JST-XH connector. Keep track of which cable corresponds to which valve and label the wire and valves appropriately.

Power and synchronisation cables

The power cable in the record system simply supplies the valves with the power they need to operate. This is done by connecting the cable to the RECORD circuit board, which in turn supplies that voltage to the relays that open and close the circuit that carries the external power source voltage. The synchronisation cables on the other hand simply serve as a link between the RECORD system and an external system. How the synchronisation cables are built will vary with respect to the external system that is in use, but the end of the cable that connects to RECORD will be the same.

Herein we will explain how to build synchronisation cables for the Noldus Ethovision system and the Inscopix nVista DAQ box system.

Materials

- Speaker wire (x 1)
- Cat 5 cable (Noldus) (x 1)
- Coaxial cable (Inscopix) (x 1)
- Dupont wire or dupont connectors crimpable pins and housings (2 female, 2 male)
- 2-position JST-XH connector housing (x 2)
- XH crimpable pins (x 4)
- Soldering iron and solder
- Wire cutters

- Wire strippers (0.80 - 2.6 mm^2, AWG 10-20)
- Crimper (0.1 - 0.5 mm^2, AWG 26-20)

Power cable

1. **Preparing the cable**
   Using the wire cutters, measure and cut a section of **speaker cable.** The segment should be long enough to put some amount of distance between the RECORD electronics and power supply. It is recommended that this distance is measured beforehand and to add about 1 metre to it for slack.
   Strip both ends of the speaker wire. One end will need male dupont connectors and the other will be housed by a 2-pin JST-XH connector.

   Prepare 2 wires with one male dupont connector each and 2 with an XH pin on one end. The other end of each of these wires should be stripped and prepared for soldering. Alternatively, the pins and connectors may be crimped onto the speaker wire directly if the wire is small enough to fit in the crimp.

2. **Soldering Preparation**

   Make sure the soldering iron is resting in its holder and nothing is touching the metal tip at the end. The soldering iron will get *very hot very quickly!* It's important to handle this device with care. Turn the soldering iron on and wait for it to heat up. *DO NOT HOLD THE SOLDERING IRON BY THE TIP, YOU WILL BURN YOURSELF. Always grab the soldering iron by its* ***heat insulated padding.***

3. **Creating the connectors on the wire**

   Solder a wire or crimp an XH connector pin to each of the internal wires on one end of the speaker cable. Make one of these wires as "GROUND" and make sure to keep track of it.

   On the other end of the cable, solder or crimp a male dupont connector to both of the internal speaker wires.

   Lastly, introduce the two XH pin wires into the JST-XT housing. Pin 5 will house the 4-wire joint wire and pins 1 through 4 will house the remaining wires.

4. **Identify the appropriate wires on the Noldus synchronisation cable**

   Using the following diagram, taken from the "USB-IO box / Mini USB-IO box for EthoVision XT 13.0" reference guide, identify and solder the female dupont wires to "Add-On Supply V+ 18 Volt" and "ground" and connect them to the cable you just made.

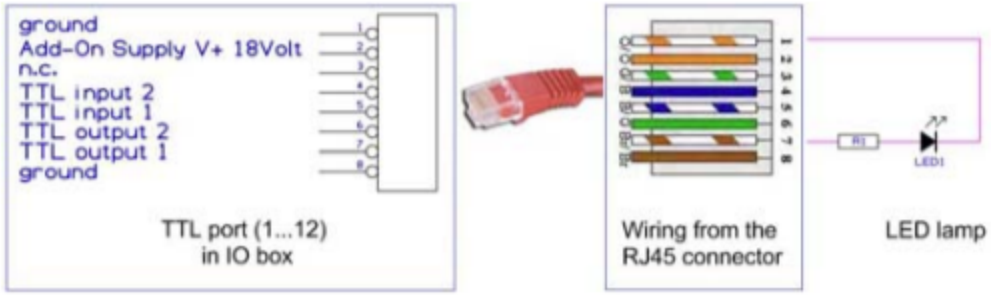


Figure 6 *Wiring scheme for connecting a LED lamp.*

Noldus synchronisation cable

1. **Preparing the cable**

   Follow the same steps followed for the **power cable**, but instead of using male dupont connectors, use female connectors. This will create a detachable interface between the RECORD system's cable and the Noldus sync cable.

   Because the Noldus I/O box uses ethernet connections, we will be using a CAT5 cable for synchronisation. Expose the ends of each internal wire in the CAT5 cable to prepare them for soldering/crimping.

2. **Identify the CAT5 wires**

   Using the following diagram, taken from the "USB-IO box / Mini USB-IO box for EthoVision XT 13.0" reference guide, identify and solder the male dupont wires to "TTL input 1" and ground and connect them to the cable prepared in step 1. Solder additional wires if needed, but be sure to make more sync cables for any other TTL being used.

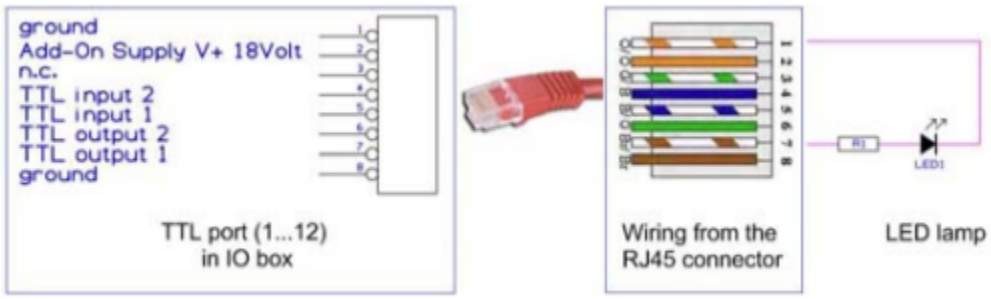


Figure 6 *Wiring scheme for connecting a LED lamp.*

Inscopix synchronisation cable

1. **Preparing the cable**
   Using the wire cutters, measure and cut a section of **coaxial cable.** The segment should be long enough to put some amount of distance between the RECORD electronics and power supply. It is recommended that this distance is measured beforehand and to add about 1 metre to it for slack.
   Expose the internals of this cable. The outer shielding will need to be grounded and the internal conductor will carry the TTL signal.

   You'll need a wire with an XH pin crimped onto it and a wire with a female dupont connector for this build. The other end of each of these wires should be stripped and prepared for soldering.

5. **Soldering Preparation**

   Make sure the soldering iron is resting in its holder and nothing is touching the metal tip at the end. The soldering iron will get *very hot very quickly!* It's important to handle this device with care. Turn the soldering iron on and wait for it to heat up. *DO NOT HOLD THE SOLDERING IRON BY THE TIP, YOU WILL BURN YOURSELF. Always grab the soldering iron by its* ***heat insulated padding.***

6. **Creating the connectors on the wire**

   Solder the XH wire to the internal conductor of the coax cable, then solder the dupont wire to the wire that wraps around the coax shielding. Mark the dupont wire as "GROUND". Wrap all exposed cable internals with electrical tape, making sure that the shielding wire does not touch the internal conductor wire, then insert the XH wire into the JST-XH housing.

7. **Grounding the coaxial shielding**

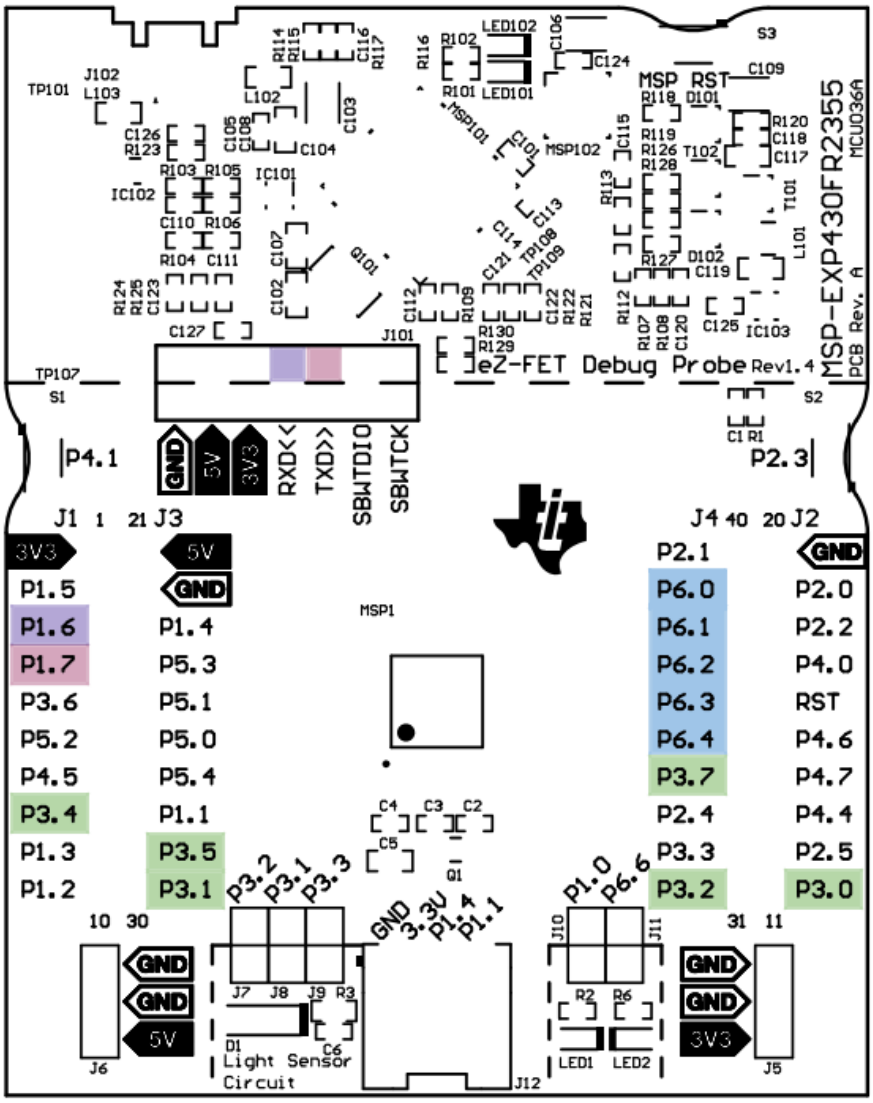
   Connect the dupont wire that was soldered to the shielding wire on the coax cable directly to a GROUND pin on the microcontroller. This will ensure that the TTL signal is clean and does not float.

Hardware connections

Microcontroller

The microcontroller unit (MCU) provides control for all electronic components in the RECORD system (excluding any external spatial tracking software). The following table and figure describe the pin that drives each electronic component. All connections from the MCU to its respective component listen on the table below (with the exception of the eUSCI pins) are indirect, as they pass first through the printed circuit board (PCB). We use the Texas Instruments MSP-EXP430FR2355 launchpad development kit (https://www.ti.com/tool/MSP-EXP430FR2355). For additional documentation on this microcontroller, please visit the manufacturers website (https://www.ti.com/product/MSP430FR2355).

Peripheral Type	**Associated Electronic Component**	**Pin on MSP430-FR2355 Launchpad**
GPIO	TTL out (ACK signal)	P3.0
GPIO	Relay 1 or 5	P3.1
GPIO	Relay 2 or 6	P3.2
GPIO	Relay 3 or 7	P3.7
GPIO	Relay 4 or 8	P3.4
GPIO	TTL in (SYNC signal)	P3.5
Capture/Compare Output, Timer B1 (PWM)	Cost LED Ring 1	P6.0
Capture/Compare Output, Timer B2 (PWM)	Cost LED Ring 2	P6.1
Capture/Compare Output, Timer B3 (PWM)	Cost LED Ring 3	P6.2
Capture/Compare Output, Timer B4 (PWM)	Cost LED Ring 4	P6.3
Capture/Compare Output, Timer B5 (PWM)	Trial Indicator LED	P6.4
eUSCI, UART RXD	Serial Communication Receive	P1.6
eUSCI, UART TXD	Serial Communication Transmit	P1.7

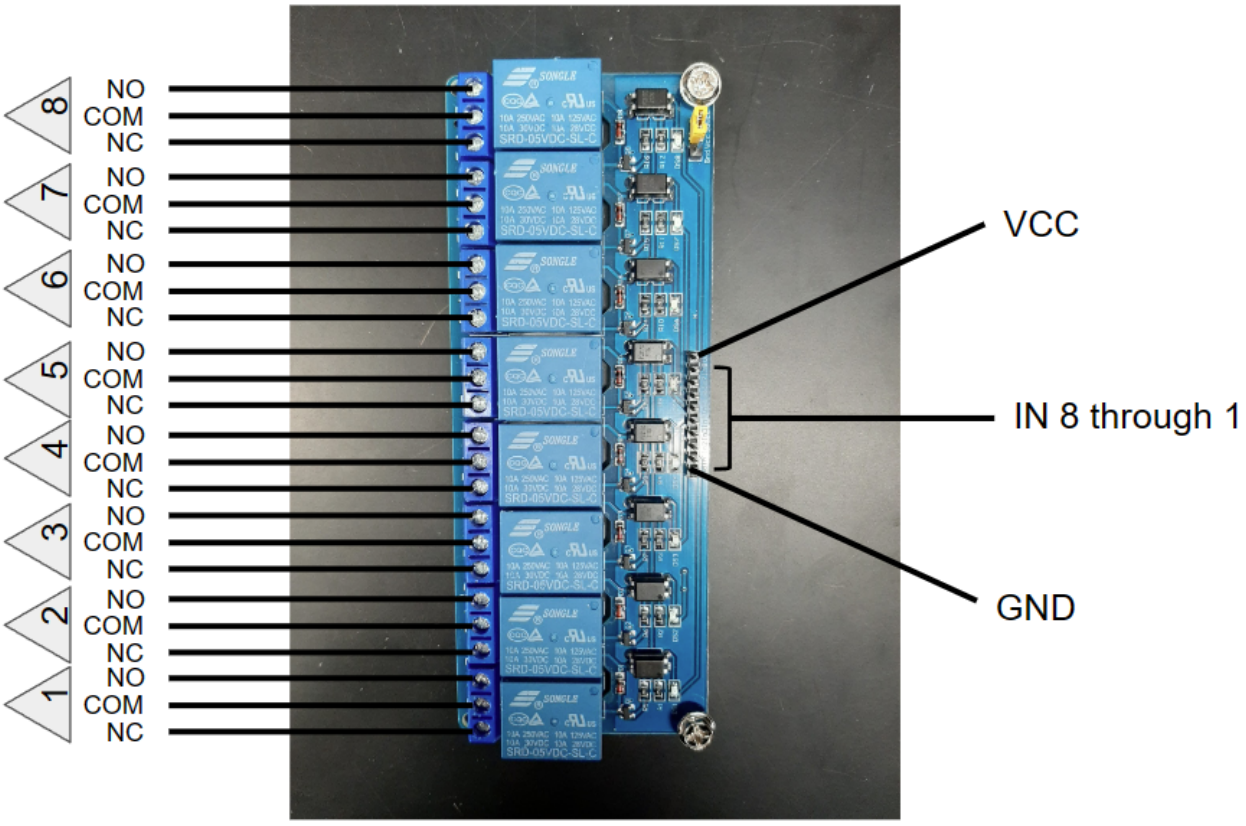


PCB layout image credit to Texas Instruments.
https://www.ti.com/tool/MSP-EXP430FR2355#design-files (SLAR152.zip, "MSP-EXP430FR2355_PCBlayers.pdf" pg. 1)

Relay Shield

Position on Relay Shield	**Connection on PCB**	**Name**

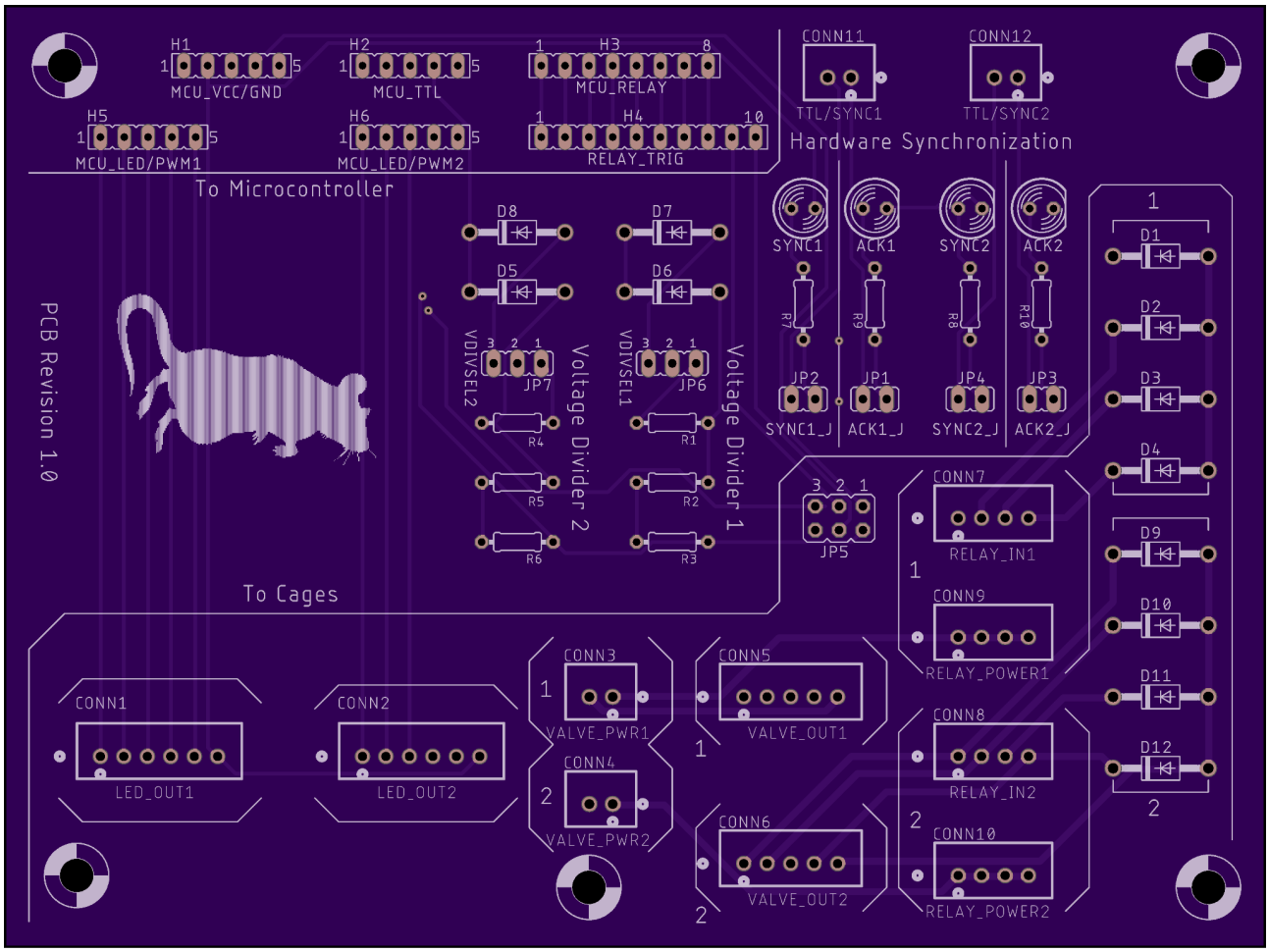
(For each relay)		
VCC	H4.9	Positive power supply
GND	H4.10	Ground
NO	CONN7.x / CONN8.x	Normally open terminal
NC	Not Connected	Normally closed terminal
COM	CONN9.x / CONN10.x	Common voltage terminal
INx (1 through 8)	H4.x (1 through 8)	Input trigger signal terminal



Printed Circuit Board (PCB)

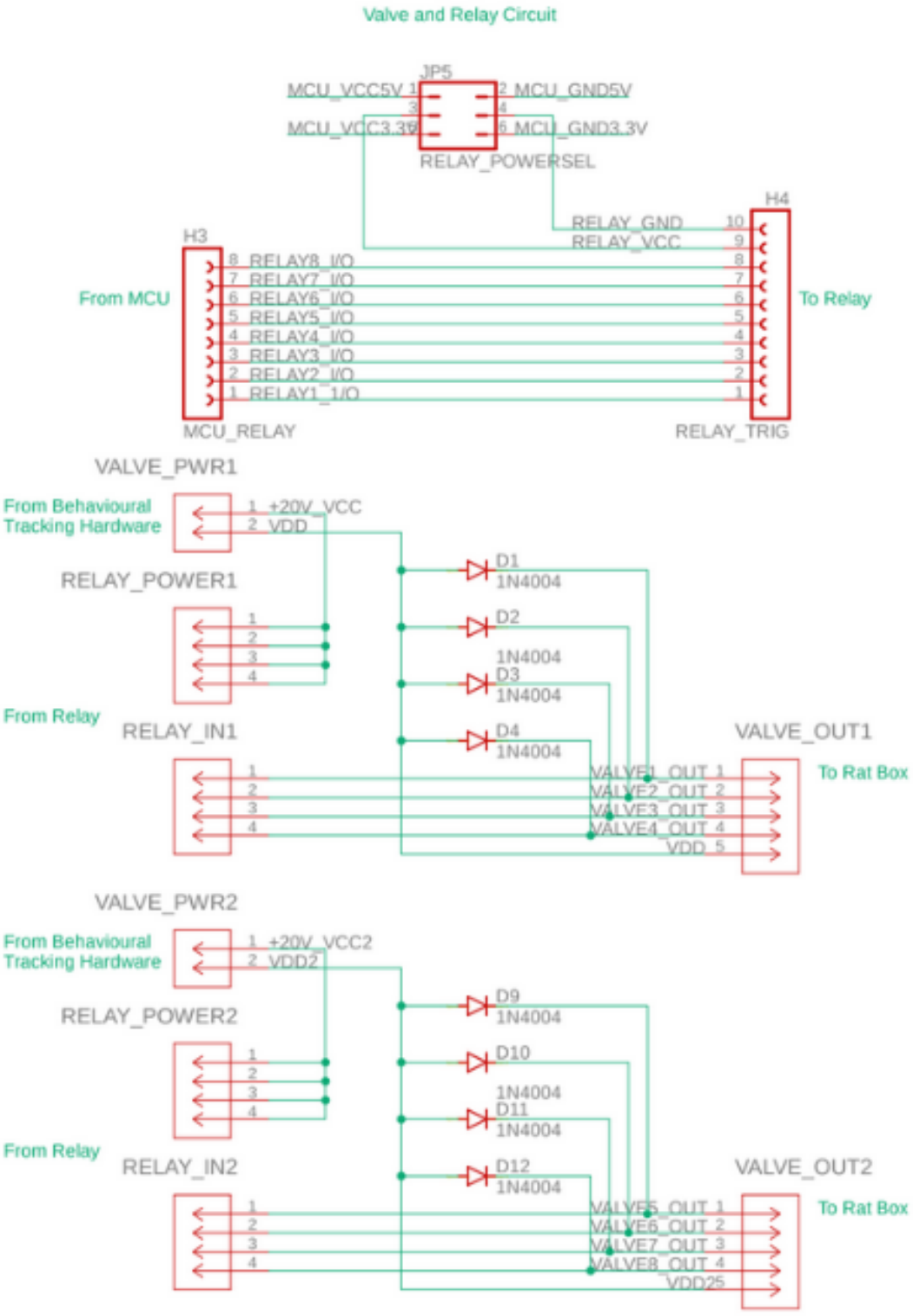
The PCB can relay up to two different RECORD microcontroller inputs and outputs, or drive up to eight cost/reward components from a single microcontroller, if the firmware and hardware

allow it. No cost/reward components are connected directly to the microcontroller, rather, they are connected to the PCB to be held tightly in place, while the PCB is connected to the microcontroller through jumper wires. See “Microcontroller, Relay, and PCB connections” for a detailed connection table.

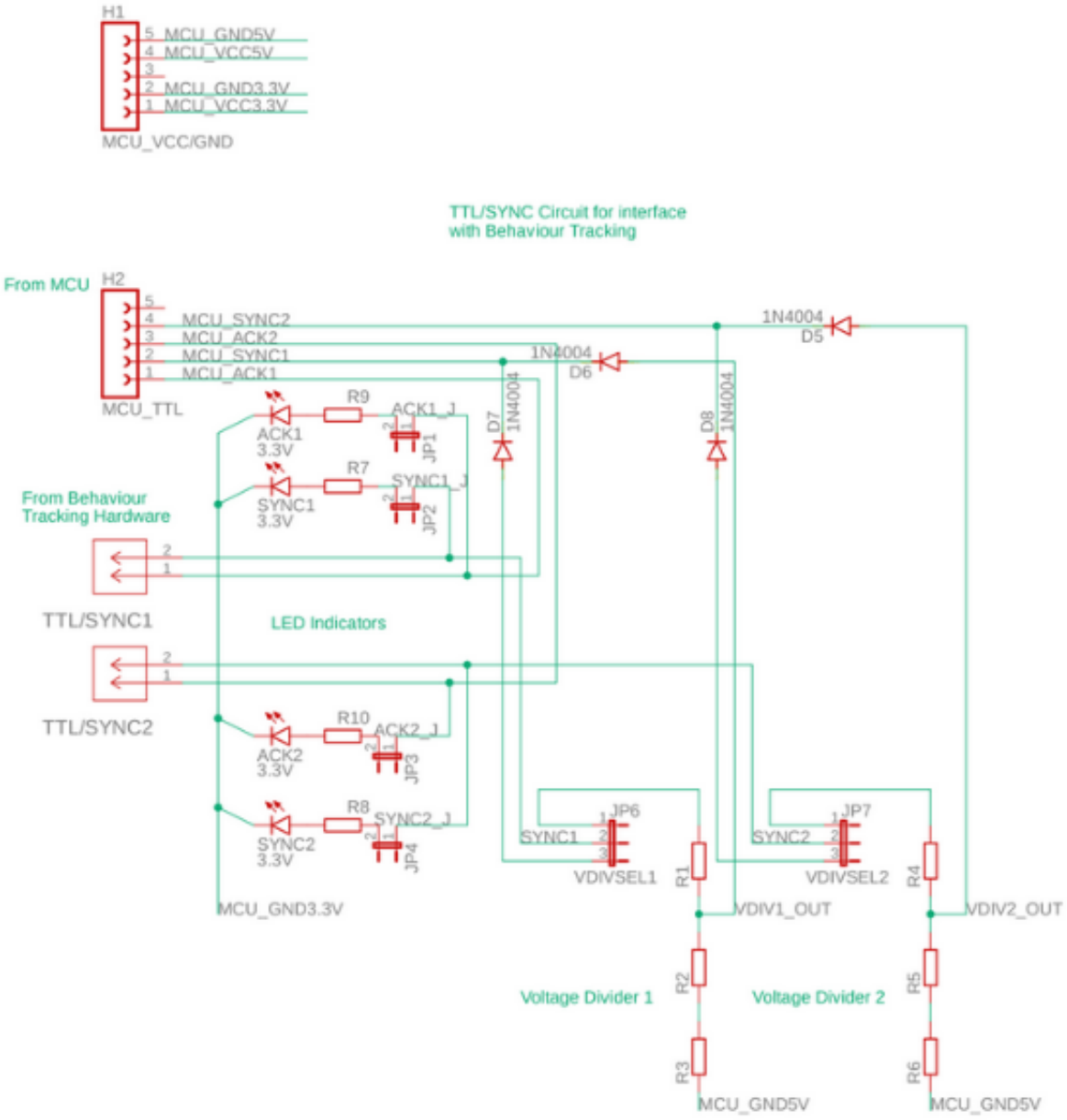


Custom RECORD PCB, Revision 1.0

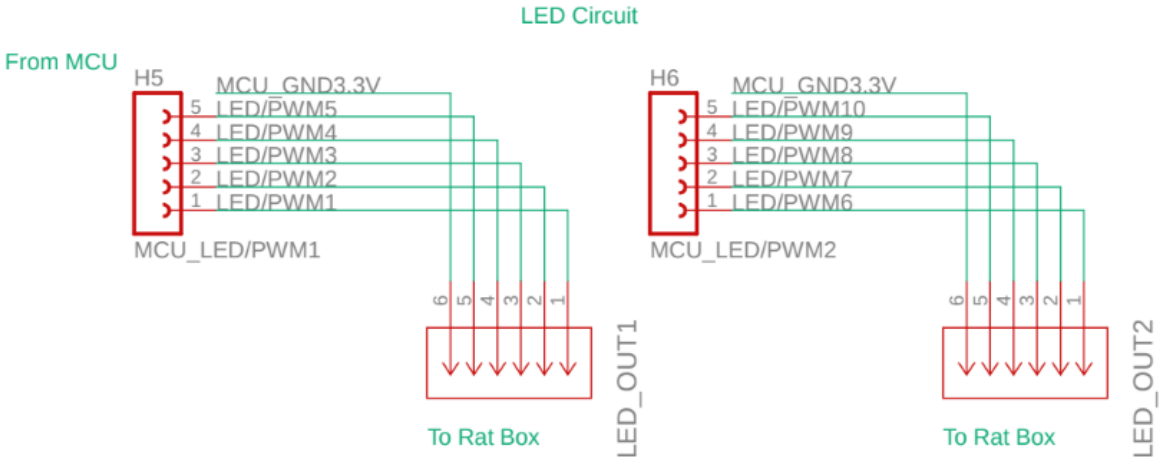
PCB schematics



Custom RECORD PCB schematic, generated in Autodesk Eagle, PCB Revision 1.0



Custom RECORD PCB schematic, generated in Autodesk Eagle, PCB Revision 1.0



Custom RECORD PCB schematic, generated in Autodesk Eagle, PCB Revision 1.0

List of components

PCB Position	Manufacturer	Part Number	Value	Units	Component type
R1*	Sparkfun	COM-10969	2.2* ± 5	kΩ %	Resistor
R2*	Sparkfun	COM-10969	3.3* ± 5	kΩ %	Resistor
R3*	Sparkfun	COM-10969	0*	Ω	Resistor
R4*	Sparkfun	COM-10969	2.2* ± 5	kΩ %	Resistor
R5*	Sparkfun	COM-10969	3.3* ± 5	kΩ %	Resistor
R6*	Sparkfun	COM-10969	0*	Ω	Resistor
R7*	Sparkfun	COM-10969	0*	Ω	Resistor
R8*	Sparkfun	COM-10969	0*	Ω	Resistor
R9*	Sparkfun	COM-10969	0*	Ω	Resistor
R10*	Sparkfun	COM-10969	0*	Ω	Resistor
D1	Vishay General Semiconductors	1N4007E-E3/54	V_f = 1.1 V_r = 1000	V	Diode
D2	Vishay General Semiconductors	1N4007E-E3/54	V_f = 1.1 V_r = 1000	V	Diode
D3	Vishay General Semiconductors	1N4007E-E3/54	V_f = 1.1 V_r = 1000	V	Diode
D4	Vishay General Semiconductors	1N4007E-E3/54	V_f = 1.1 V_r = 1000	V	Diode
D5	Vishay General	1N4007E-E3/54	V_f = 1.1 V_r = 1000	V	Diode

	Semiconductors				
D6	Vishay General Semiconductors	1N4007E-E3/54	V_f = 1.1 V_r = 1000	V	Diode
D7	Vishay General Semiconductors	1N4007E-E3/54	V_f = 1.1 V_r = 1000	V	Diode
D8	Vishay General Semiconductors	1N4007E-E3/54	V_f = 1.1 V_r = 1000	V	Diode
D10	Vishay General Semiconductors	1N4007E-E3/54	V_f = 1.1 V_r = 1000	V	Diode
D11	Vishay General Semiconductors	1N4007E-E3/54	V_f = 1.1 V_r = 1000	V	Diode
D12	Vishay General Semiconductors	1N4007E-E3/54	V_f = 1.1 V_r = 1000	V	Diode
H1	Samtec Inc	TSW-105-07-T-S	Pitch = 2.54 Position = 5	mm	Board to Board Header
H2	Samtec Inc	TSW-105-07-T-S	Pitch = 2.54 Position = 5	mm	Board to Board Header
H3	Samtec Inc	TSW-108-07-T-S	Pitch = 2.54 Position = 8	mm	Board to Board Header
H4	Samtec Inc	TSW-110-07-T-S	Pitch = 2.54 Position = 10	mm	Board to Board Header
H5	Samtec Inc	TSW-105-07-T-S	Pitch = 2.54 Position = 5	mm	Board to Board

					Header
H6	Samtec Inc	TSW-105-07 -T-S	Pitch = 2.54 Position = 5	mm	Board to Board Header
JP1	Samtec Inc	TSW-102-07 -T-S	Pitch = 2.54 Position = 2	mm	Board to Board Header
JP2	Samtec Inc	TSW-102-07 -T-S	Pitch = 2.54 Position = 2	mm	Board to Board Header
JP3	Samtec Inc	TSW-102-07 -T-S	Pitch = 2.54 Position = 2	mm	Board to Board Header
JP4	Samtec Inc	TSW-102-07 -T-S	Pitch = 2.54 Position = 2	mm	Board to Board Header
JP5	Samtec Inc	TSW-103-07 -T-S	Pitch = 2.54 Position = 3 Rows = 2	mm	Board to Board Header
JP6	Samtec Inc	TSW-103-07 -T-S	Pitch = 2.54 Position = 3	mm	Board to Board Header
JP7	Samtec Inc	TSW-103-07 -T-S	Pitch = 2.54 Position = 3	mm	Board to Board Header
CONN1	Qibaok	XH-6A	Pitch = 2.54 Female Position = 6	mm	JST-XH Female Header
CONN2	Qibaok	XH-6A	Pitch = 2.54 Female Position = 6	mm	JST-XH Female Header
CONN3	Qibaok	XH-2A	Pitch = 2.54 Female Position = 2	mm	JST-XH Female Header
CONN4	Qibaok	XH-2A	Pitch = 2.54 Female Position = 2	mm	JST-XH Female Header
CONN5	Qibaok	XH-5A	Pitch = 2.54	mm	JST-XH

			Female Position = 5		Female Header
CONN6	Qibaok	XH-5A	Pitch = 2.54 Female Position = 5	mm	JST-XH Female Header
CONN7	Qibaok	XH-4A	Pitch = 2.54 Female Position = 4	mm	JST-XH Female Header
CONN8	Qibaok	XH-4A	Pitch = 2.54 Female Position = 4	mm	JST-XH Female Header
CONN9	Qibaok	XH-4A	Pitch = 2.54 Female Position = 4	mm	JST-XH Female Header
CONN10	Qibaok	XH-4A	Pitch = 2.54 Female Position = 4	mm	JST-XH Female Header
CONN11	Qibaok	XH-2A	Pitch = 2.54 Female Position = 2	mm	JST-XH Female Header
CONN12	Qibaok	XH-2A	Pitch = 2.54 Female Position = 2	mm	JST-XH Female Header
SYNC1*	Kingbright Company LLC	WP7113VBC/D	V_f = 3.3** Lens = 5	V mm	Light Emitting Diode (LED)
ACK1*	Kingbright Company LLC	WP7113VBC/D	V_f = 3.3** Lens = 5	V mm	Light Emitting Diode (LED)
SYNC2*	Kingbright Company LLC	WP7113VBC/D	V_f = 3.3** Lens = 5	V mm	Light Emitting Diode (LED)
ACK2*	Kingbright Company LLC	WP7113VBC/D	V_f = 3.3** Lens = 5	V mm	Light Emitting Diode (LED)

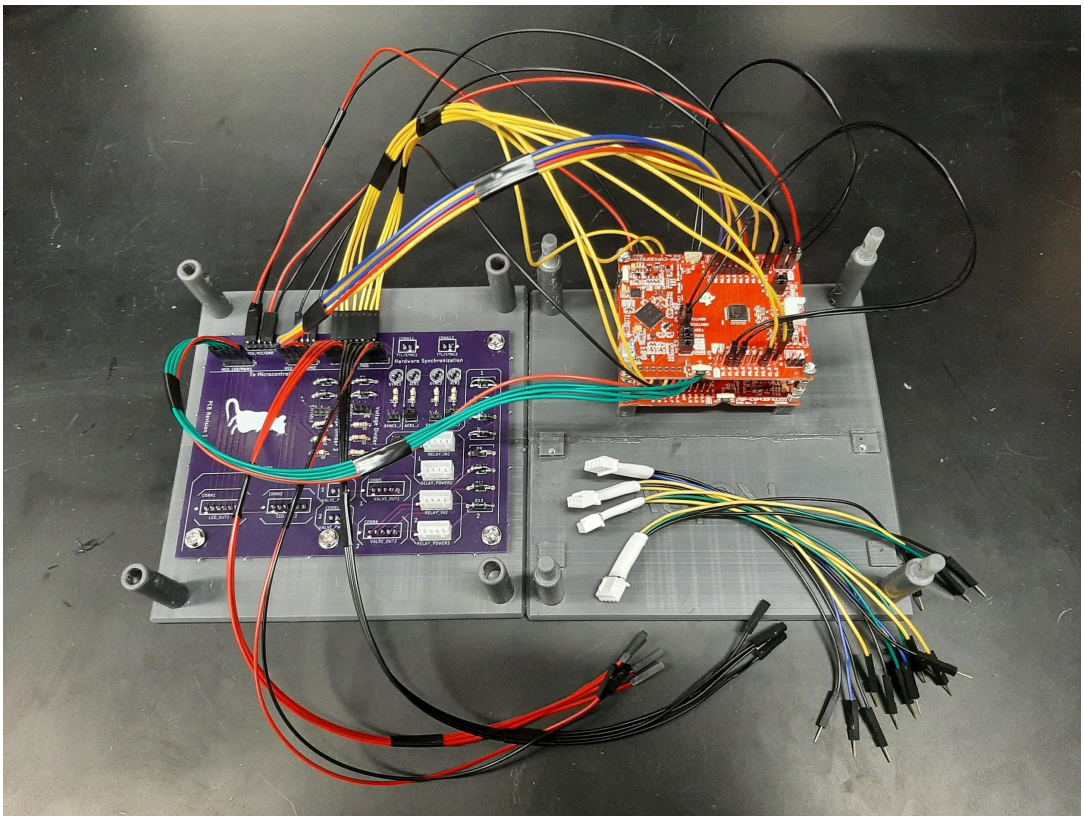
* Components and values reflect what was used for our particular setup. These Values should be chosen according to each system's requirements

** Different LED forward voltages may be needed depending on each individual system. The LED should be able to turn on with its corresponding TTL signal voltages delivered by the

microcontroller and voltage divider output. Voltage divider output is dependent on R1, R2, and R3 for SYNC1 and ACK1, as well as R4, R5, and R6 for SYNC2 and ACK2. Value shown is the typical operating voltage for the LED, see component datasheet for maximum and minimum forward voltages.

Internal Connectors:
Pictured in the image below (bottom right), they serve to connect the PCB to the relay shield input/outputs.

CONN7	Qibaok	XH-4Y	Pitch = 2.54 Male Position = 4	mm	JST-XH Male Connector
CONN8	Qibaok	XH-4Y	Pitch = 2.54 Male Position = 4	mm	JST-XH Male Connector
CONN9	Qibaok	XH-4Y	Pitch = 2.54 Male Position = 4	mm	JST-XH Male Connector
CONN10	Qibaok	XH-4Y	Pitch = 2.54 Male Position = 4	mm	JST-XH Male Connector



Microcontroller, Relay, and PCB Connections

Connections for MCU 1

Signal	Position on MCU (MSP430-FR2355)	Position on PCB	Position on Relay Shield
Cost LED1	P6.0	H5.1	-
Cost LED2	P6.1	H5.2	-
Cost LED3	P6.2	H5.3	-
Cost LED4	P6.3	H5.4	-
Trial Indicator LED	P6.4	H5.5	-
Low-Voltage Supply*	3V3 or 5V*	H1.1	-
Ground	GND	H1.2	-
SYNC	P3.5 or P3.6***	H2.1	-
ACK	P3.0***	H2.2	-
Trigger Signal for Relay 1	P3.1	H3.1	-
Trigger Signal for Relay 2	P3.2	H3.2	-
Trigger Signal for Relay 3	P3.7	H3.3	-
Trigger Signal for Relay 4	P3.4	H3.4	-
MCU to Relay 1	-	H4.1	IN1
MCU to Relay 2	-	H4.2	IN2
MCU to Relay 3	-	H4.3	IN3
MCU to Relay 4	-	H4.4	IN4
Relay VCC	-	H4.9	VCC
Relay GND	-	H4.10	GND
Relay 1 to Valve 1	-	CONN7.1	Relay 1, Normally Open Terminal

Relay 2 to Valve 2	-	CONN7.2	Relay 2, Normally Open Terminal
Relay 3 to Valve 3	-	CONN7.3	Relay 3, Normally Open Terminal
Relay 4 to Valve 4	-	CONN7.4	Relay 4, Normally Open Terminal
Common High-voltage supply for valves 1 - 4	-	CONN9.1-4**	Relay 1-4, COM Terminal

* Supplying low-voltage power to the PCB serves to route the voltage and ground to the relay shield. Make sure you are providing enough power to the relay shield and that the jumpers on JP5 are configured in the correct way to carry that voltage. The relay shield may be able to operate on 3.3V, however 5V is recommended.
** Connector 9 simply supplies voltage to the relay. The COM terminal is shorted with the Normally Open terminal when the relay is activated. The order in which the pins on the connector are connected to each relay's COM terminal has no effect on the function of the system.
*** This connection depends on the particular use-case scenario. P3.0 is the outgoing ACK signal that pulses every time a command is executed, P3.5 is an user-triggerable outgoing TTL signal, and P3.6 is for incoming TTL signals. Incoming TTL signals must be stepped down to 3.3V to not damage the system. Care must be taken when selecting what should be connected where.

Connections for MCU 2

Signal	Position on MCU	Position on PCB	Position on Relay Shield
Cost LED1	P6.0	H6.1	-
Cost LED2	P6.1	H6.2	-
Cost LED3	P6.2	H6.3	-
Cost LED4	P6.3	H6.4	-
Trial Indicator LED	P6.4	H6.5	-
Low-Voltage Supply*	3V3 or 5V*	H1.3	-
Ground	GND	H1.4	-
SYNC	P3.5 or P3.6***	H2.4	-
ACK	P3.0***	H2.5	-
Trigger Signal for Relay 1	P3.1	H3.5	-
Trigger Signal for Relay 2	P3.2	H3.6	-
Trigger Signal for Relay 3	P3.7	H3.7	-
Trigger Signal for Relay 4	P3.4	H3.8	-
MCU to Relay 1	-	H4.5	IN5
MCU to Relay 2	-	H4.6	IN6
MCU to Relay 3	-	H4.7	IN7
MCU to Relay 4	-	H4.8	IN8
Relay VCC	-	H4.9	VCC
Relay GND	-	H4.10	GND
Relay 5 to Valve 1	-	CONN8.1	Relay 5, Normally Open Terminal
Relay 6 to Valve 2	-	CONN8.2	Relay 6, Normally Open Terminal

Relay 7 to Valve 3	-	CONN8.3	Relay 7, Normally Open Terminal
Relay 8 to Valve 4	-	CONN8.4	Relay 8, Normally Open Terminal
Common High-voltage supply for valves 1 - 4	-	CONN10.1-4**	Relay 5-8, COM Terminal

* Supplying low-voltage power to the PCB serves to route the voltage and ground to the relay shield. Make sure you are providing enough power to the relay shield and that the jumpers on JP5 are configured in the correct way to carry that voltage. The relay shield may be able to operate on 3.3V, however 5V is recommended.
** Connector 10 simply supplies voltage to the relay. The COM terminal is shorted with the Normally Open terminal when the relay is activated. The order in which the pins on the connector are connected to each relay's COM terminal has no effect on the function of the system.
*** This connection depends on the particular use-case scenario. P3.0 is the outgoing ACK signal that pulses every time a command is executed, P3.5 is an user-triggerable outgoing TTL signal, and P3.6 is for incoming TTL signals. Incoming TTL signals must be stepped down to 3.3V to not damage the system.

Resource table

[Under construction]