MQTT 5 Ray Detector Instructions

Description

The MQTT 5 Ray Detector is designed to provide occupancy detection for 5 rays in a roundhouse or staging yard. All 5 rays are driven by one driver, so it is probably not best for running multiple trains simultaneously. Its small size makes it easier to hide under the track or table.

- DCC track power, 1A current limited, voltage regulated, and short circuit protected.
- Inductive occupancy detectors, with adjustable sensitivity.
- ESP8266-based Wemos D1 Mini providing WiFi connection to MQTT and JMRI.
- User-programmable addresses for the sensor inputs.
- Built in sensor de-bouncing provided in the sketch.
- Connects to the shield on the base station that provides DCC signals and 5V power with standard CAT5 cables.

Assembly

Surface Mount Parts

The surface mount parts need to be soldered onto the board before the through-hole parts since the top surface needs to be laid flat on the “cookie sheet”. My cookie sheet is a piece of 1/16” thick aluminum big enough to cover the hot plate, with a wooden handle attached. My hot plate is actually a heater section from a semiconductor wafer oven with a digital controller.

Set the hot plate to 250^{o}C. Having the hot plate too hot will cause some of the parts to dance around when the flux boils. Check the profile included with the solder paste for details.

The surface mount parts chosen for this project are large enough to allow for manual solder paste application and part placement, even if you’re not an expert. The only exception is the driver chip on the shield.

Apply solder paste to all the pads, then place each part, being careful to observe the polarity of the diodes and orientation of the L293DD.

Place the board(s) on the cookie sheet then place the cookie sheet on the hot plate. Watch the boards carefully so you can nudge parts back into place if they move. Carefully remove and let cool when everything flows nicely.

Table 1: Surface Mount Parts Needed

Qty	Part	Value	DigiKey #	Device
3	C2,3,6	.1uF	399-C1206C104K5RAC7800CT-ND	C-USC1206
6	C5,7-11	.47uF	399-8201-1-ND	C-USC1206
1	D1	S1BBTR	1655-2315-1-ND	DIODE-DO-214AC
10	D2-11	1N4148	1N4148WTPMSCT-ND	DIODE-SOD123
1	IC1	7815DT	MC7815BDTRKGOSCT-ND	7818DT
1	IC2	L293DD	497-1390-5-ND	L293DD
1	R2	182K 1%	311-182KFRCT-ND	R-US_M1206

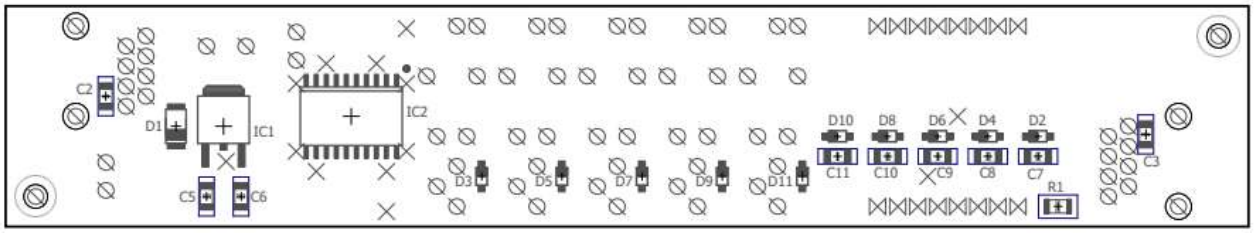

Figure 1: Surface Mount Parts Placement

After the board(s) cool, use a magnifying glass to check for bridging between the pins of the driver chip and if any is found, remove it with solder wick or a fine point soldering iron. Also check for parts that may be missing solder.

Through-Hole Parts

Figure 2: Mini with male headers installed.

Prepare the D1 Mini first. Hopefully you bought your minis with the headers included. Solder the male headers onto the D1 Mini, tacking only one pin at first to make sure the header is perpendicular to the board, then solder the rest of the pins.

To ensure good alignment of the short female headers on the circuit board, install them onto the pins of the Mini, then insert the headers and Mini into the top of the block controller board.

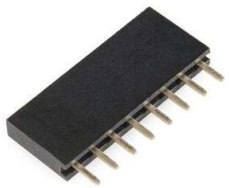

Figure 3: Short female header.

Solder the remaining pins of the headers.

Remove the Mini and install the remaining through-hole parts. Make sure to observe the polarity of C1 and C4.

Table 2: Through-Hole Parts Needed

Qty	Part	Value	DigiKey #	Device
2	C1,4	100uF	493-1107-ND	CPOL-USE3.5-8
2	J1,2	5555164-1	A31442-ND	520426-4
5	R2-6	2meg trimmer pot	3386P-1-205LF	S63P
2	X1	2 pos term block	EAN 0710560354139	(Amazon)
2	T1-5	40 turns, 1 turn	Core: EAN 0675234790876	See Instructions
1	U$1	WEMOS-D1-MINI	na	See Instructions

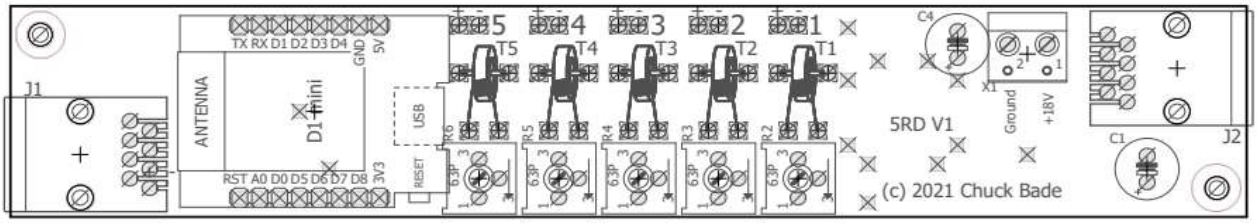

Figure 4: Through-Hole Parts Placement

The parts named T1-T5 are custom wound transformers, with around 30-40 turns of small wire, such as wire-wrap wire (AWG #30) wound around a ferrite core, with the ends connected to the pads near the pots, and one piece of hookup wire passed through the core and soldered to the pads on either side, as

shown in the artwork. This forms the inductive occupancy detectors. If it is found to be too sensitive, turns can be removed, but R1 may be able to be adjusted to bring the sensitivity down enough to be reliable.

There are five occupancy detectors on the board. The first one is comprised of C7, D2, D3, R2, and T1. When nothing is on the track, the secondary of T1 will have little or no signal, and R2 will charge C7 to around 3 volts. When a load, such as a locomotive, is placed on the track, the inductive and capacitive load will create an AC current through the single winding primary of T1, which will induce an AC voltage on the secondary. The signal on the secondary will be alternating positive and negative spikes of much greater amplitude than across the primary. One side of the secondary is connected to 3.3 volts, and the other side is connected to D3 which passes only the negative spikes to C7, causing the voltage to decrease. When this voltage is low enough (around one volt), the Mini will detect it send the Active message. D2 prevents this voltage from going much below zero and damaging the Mini. Adjusting R2 to a lower resistance will make it harder to discharge C7, so the detector will be less sensitive.

Testing

Initial testing should be done with the Mini removed.

1. Connect a 18VDC power supply to the +18V and Ground connections on the 5 ray detector and a piece of test track to the +- connections near ferrite core T1. This is track 1.
2. Connect a CAT5 cable from the base station to the block controller. It doesn’t matter which connector, they’re both the same.
3. Measure DC voltage across C2 or C3. You should see 5 volts.
4. Assuming you’re using WiThrottle, go into Settings and make sure Track Power is on.
5. Measure AC voltage across the track. You should read around 15VAC. If this is OK, skip the next step
6. On the back side of the board, find IC1, C5, and C6. IC1 is the 15V regulator. The tab side is ground, the lead next to C5 is the input and the lead next to C6 is the output. With your meter on DC, measure between ground (tab) and output. If you don't see 15v there, check the input side. If you don’t have power coming in to the board, check your wiring.
7. Turn off the power.
8. Program a mini and plug it in to the block controller. See the Programming section below.
9. Turn on the power.

10. With nothing on the track, measure DC voltage between pin Mini pin D1 (the junction of C7, D2, D3, and R2) and ground. Adjust R2 for around 2.7 volts. Place a locomotive on track 1. The voltage at Mini pin D1 should go to a close to zero and the blue LED will turn on.
11. Connect tracks 2 thru 5 and repeat step 10 for each track's detector.

If the 5 ray detector is connected to a regular length of track, the setting of R2-6 might need to be adjusted if the blue LED stays on all the time. This is due to the capacitance between the feeder wires and between the two rails of the track. This capacitance acts as an AC load on the block controller and could cause the occupancy detector to be falsely triggered. I suspect that this will be worse on N-scale than on HO or other larger gauged rails. If you find it difficult to achieve proper operation, try reducing the length of feeder wire. The ray detector was meant to be located close to the turntable rays. If instead, they are all grouped together and longer feeder wires run around the layout, the occupancy detectors may not work probably.

Programming

Numbering Inputs and Outputs

The numbers for inputs from MQTT are independent of the output numbers. They could have the same numbers as inputs or completely separate. I prefer to have my turnouts at low numbers, leave enough room for expansion, then have my signal light outputs at some higher range. The reason for this is that internally JMRI treats all outputs as turnouts, and when you want to throw a turnout with WiThrottle, having the turnouts first in the list will help you avoid doing a lot of scrolling to get to your turnouts.

A note about turntables and staging yard transfer tables. Each ray in a turntable is treated as a turnout in JMRI, and "throwing" the turnout sends a command to move the table to that ray. You need to reserve enough turnout numbers for however many rays you have. Again, these need to be lower numbers so you can select the rays with WiThrottle.

Since lights are generally set automatically, the numbers for them can be set to high values, out of the way of outputs that need more frequent access.

Each light in a signal head is one output, so remember to leave space. I have an extra output on my block controller, called "aux", so I leave an extra number for that. Since the D1 Mini that is on the block controller has up to 6 outputs, it wouldn't hurt to leave space for 6 total. For example, my first light (green) on my first block controller is at 800, and the green light on the second block controller is at 806.

So my output numbering scheme is a follows:

- 60-99 Turnouts

- 100-199 Turntables/Transfer Tables
- 800-805 1st Block (green, yellow, red, aux, future1 future2)
- 806-811 2nd Block
  …
- 944-949 25th Block

Inputs can have the same numbers as outputs, but to avoid confusion, I've chosen a different series of numbers.

- 400-499 Turnout Feedback Sensors (not currently working)
- 500-599 Block Occupancy Detectors
- 500 1st Block Detector
- 501 (future use, unused input on block controller)
- 502 2nd Block Detector
- 503 (future use)

Setting up Arduino IDE

1. Install Arduino IDE.
2. In Arduino IDE, go to File->Preferences and enter http://arduino.esp8266.com/stable/package_esp8266com_index.json into the “Additional Boards Manager URLs” field.
3. Go to Tools->Board->Boards Manager…, search for ESP8266 and press the install button for the “ESP8266 by ESP8266 Community“.

You will probably need the following libraries:

- WiFi by Arduino
- PubSubClient by Nick O'Leary
- Ethernet by various

D1 Mini Configuration

1. Go to https://github.com/chuckbade/WiFi-MQTT-Modules
2. Download the latest ino file from the MQTT 5 Ray Detector directory.
3. Open it in Arduino IDE.
4. Change the values near the top of the sketch to match your network.

5. Change the JMRISensorNumber for the ray being configured for track 1. The other sensor numbers will be the next 4 contiguous numbers.
6. Connect the Mini to the USB cable and compile the sketch.
7. After is says it is resetting the device, disconnect the Mini and connect it to the 5 ray detector.

JMRI Configuration

NOTE: You must have JMRI version **4.21.1** or newer for MQTT to work with sensors.

1. From the main PanelPro menu, go to **Tools → Tables → Sensors**.
2. Click **Add…**. The **Add New Sensor** dialog will appear.
3. If **System Connection** is not showing **MQTT**, select it in the pull-down. If MQTT is not listed in the pull-down, then the installed version of JMRI is too old. See the note above.
4. Enter your desired sensor number in the **Hardware Address** field.
5. Enter a name for the turnout sensor in the **User Name** field.
6. Click **Create**. The new sensor should now be listed in the sensor table.
7. Repeat steps 2 through 6 for each ray's occupancy detector.
8. Don't forget to save your changes. (File->Store->Store Configuration and Panels to File…)