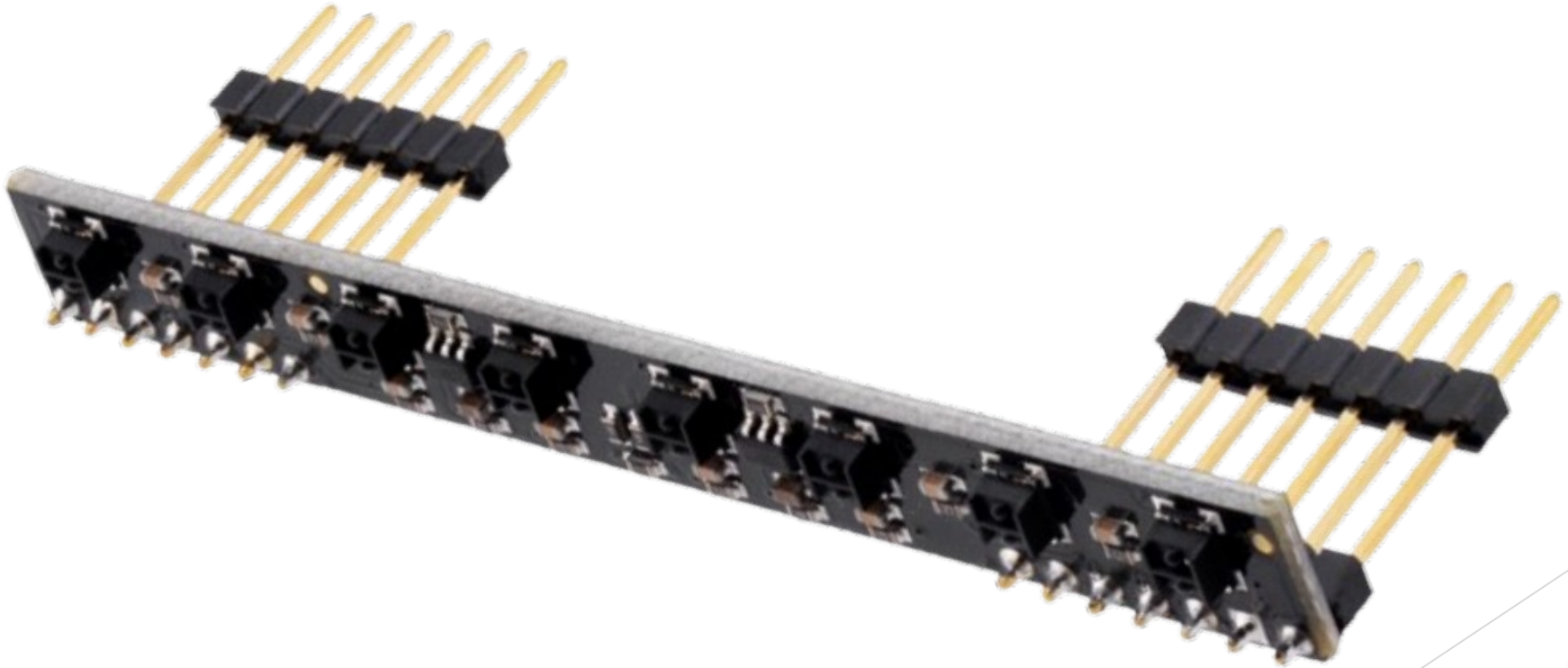
8-Channel Sensor Array and Line Follower FSM

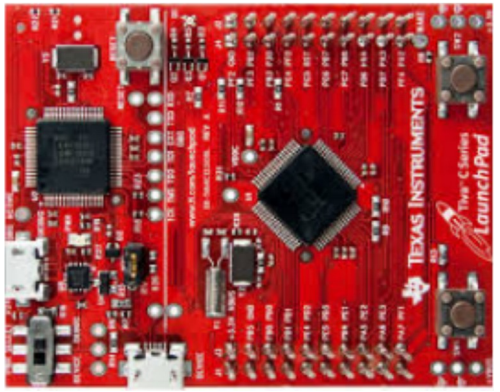
By Mark Joseph Austria, Tylor Franca Pires, and Min He



8-Channel Sensor Array

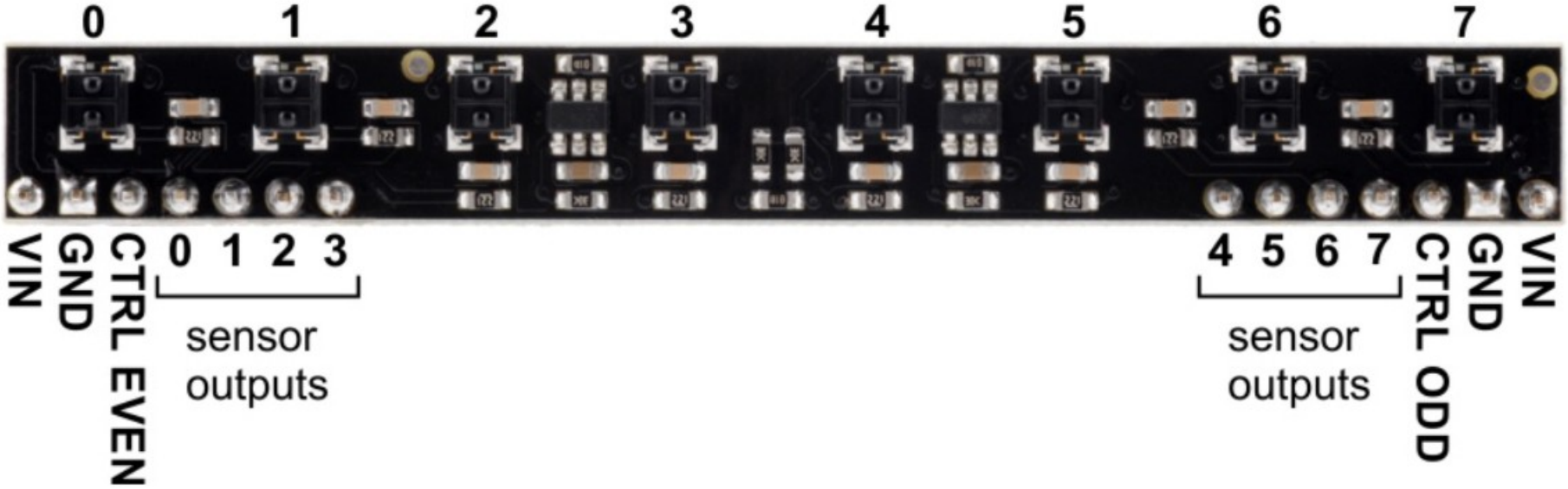
- The 8-Channel Sensor Array is a reflectance sensor module.
- The module features eight IR LED/phototransistor pairs that are great for identifying changes in reflectance.
- The sensor array offers dimmable brightness control with separate controls for the odd and even emitters.
- Each sensor provides an independent output that can be measured with a digital I/O.
- Electrical features:
  - Operating voltage: 2.9v – 5.5v
  - Full-brightness LED current: 3mA (independent of supply voltage)
  - Output format: digital I/O-compatible signals that can be read in parallel as timed high pulses.

8-Channel Sensor Array & TM4C



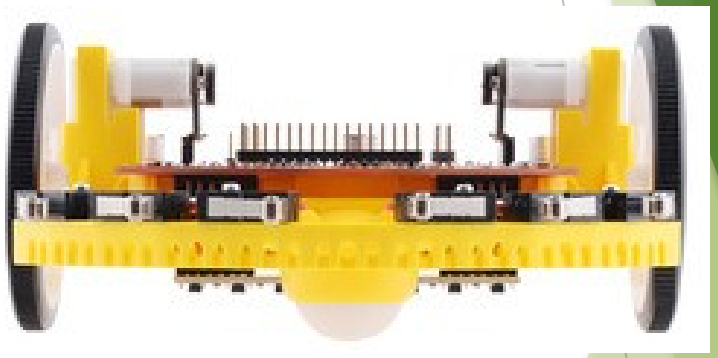
- With the help of TM4C, the sensor can differentiate a white line to a black line
- The TM4C MCU charges a capacitor to the sensor array. Then the sensor pin is set to input. Once sensor pin is set to input, the capacitor begins to discharge.
- The discharge rate depends on the amount of light detected by the light-sensitive transistor.
- More current flows to the transistor's collector-emitter path when it detects a white surface compared to a black surface.

Hardware Pinouts



- CTRL Pins (EVEN & ODD) are emitter control pins that independently control the infrared (IR) emitters
- CTRL ODD controls the odd-numbered sensors (1,3,5,7)
- CTRL EVEN controls the even-numbered sensors (0,2,4,6)
- CTRL pins and Sensor Pins connect directly to GPIO pins.

Mounting Reflectance Sensor to Romi Chassis Car



The sensor should be facing the ground with 3mm away from the ground.

Typical Sequence of Reading the Sensor

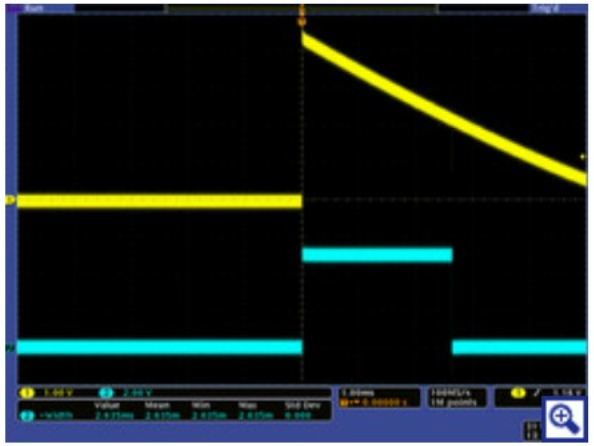
1. Turn on IR LEDs.
2. Set the I/O line to an output and drive it high.
3. Allow at least 10 µs for the sensor output to rise.
4. Make the I/O line an input (high impedance).
5. Measure the time for the voltage to decay by waiting for the I/O line to go low.
6. Turn off IR LEDs.

TTL Signals

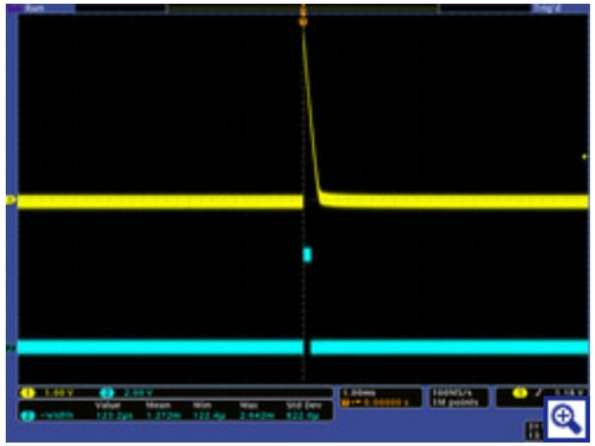
- A TTL signal, short for transistor-transistor logic, is a binary digital signal that uses two voltage levels to represent "on" or "off" states, typically 0V (logic 0) and 3.3V or 5V (logic 1). These signals are commonly used in electronics to control devices or transmit data.
- The voltage level of a TTL signal determines the logic state. Low voltage (0V to 0.8V) represents a "0" (off), while a higher voltage (2V to 5V) represents a "1" (on).
- TTL logic is based on the use of transistors to switch between the two voltage levels.
- TTL signals are used in various electronic applications, including digital circuits, microcontrollers, and communication systems.

Measuring the Decay Time of a Sensor Output

- The decay time is determined by the reflectance: the stronger the reflectance, the short the decay time. White surface has a strong reflectance, and black surface has a weak reflectance. See the measuring results below.
- Meaningful results can be available within 1 ms in typical cases, which allows up to 1 kHz sampling of all sensors.

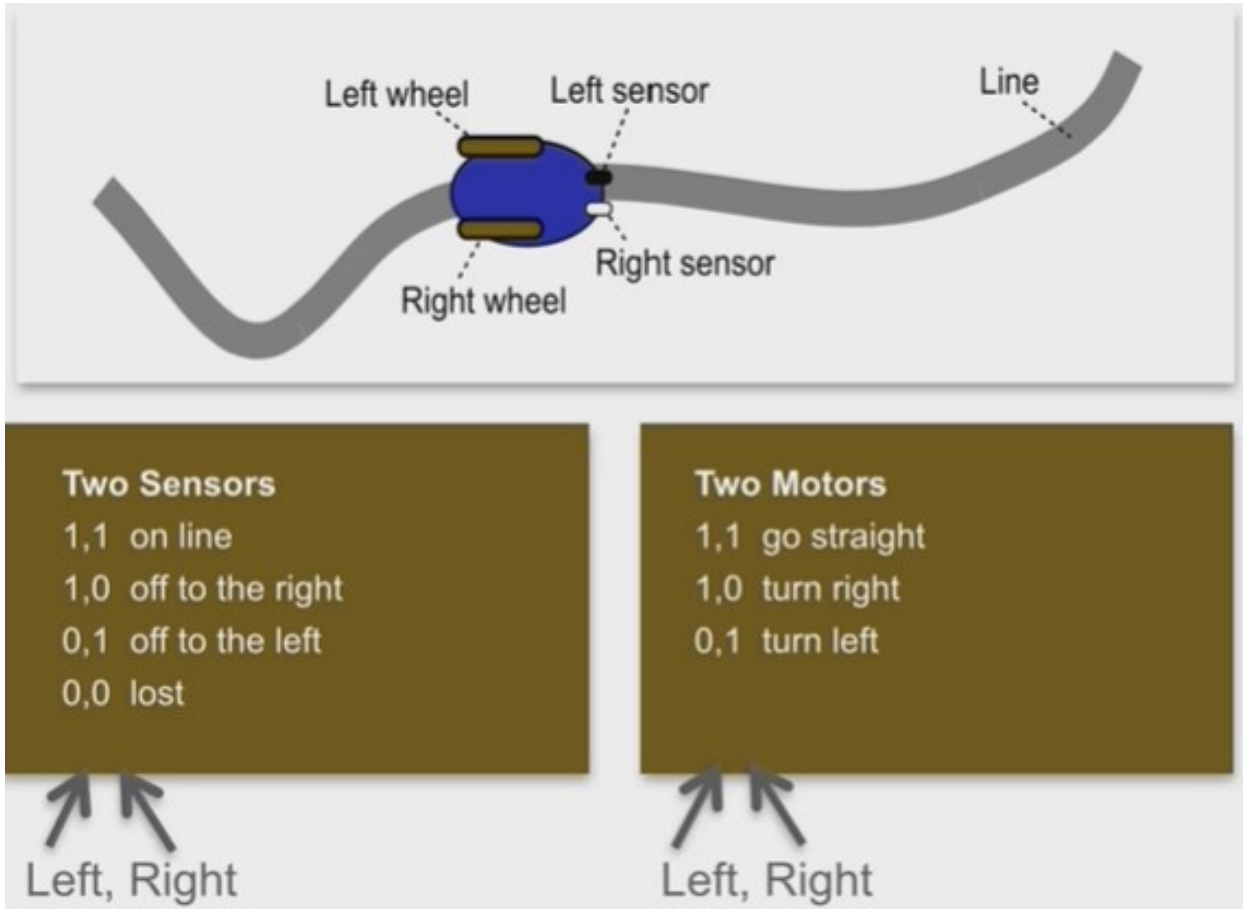


QTR-1RC output (yellow) when 1/8" above a black line and microcontroller timing of that output (blue).



QTR-1RC output (yellow) when 1/8" above a white surface and microcontroller timing of that output (blue).

Sensor with FSM



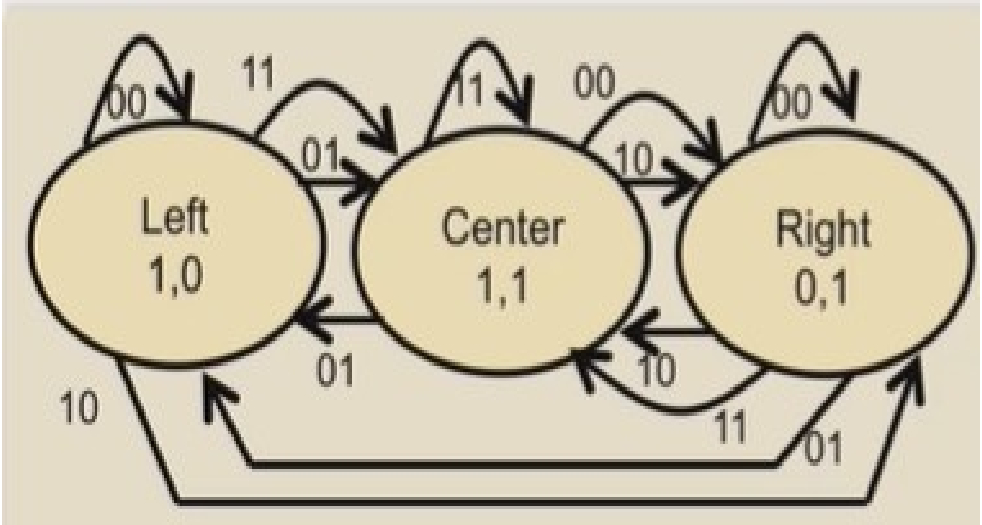
Sensor Input

Motor Output

The Sensor would read the line. Bit 0 is the right sensor and Bit 1 is the left sensor.

Based on the sensor's inputs, the motors would respond to align itself and get it to 1,1 state.

Sensor with 3 State FSM




```
State_t  fsm[3]={
  {0x03, 1, {Right, Left, Right,   Center }},
  {0x02, 1, {Left, Center, Right,  Center }},
  {0x01, 1, {Right, Left, Center,  Center }}
};
```

Sensor with 3 State FSM

State	Motor	In=0,0	In=0,1	In=1,0	In=1,1
Center	1,1	Right	Left	Right	Center
Left	***1,0***	***Left***	***Center***	***Right***	***Center***
Right	0,1	Right	Left	Center	Center

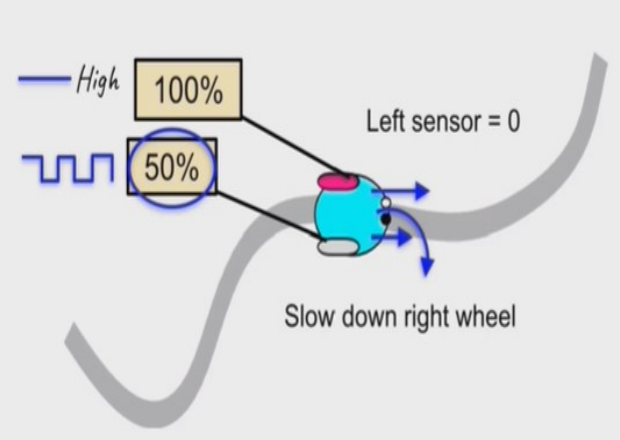
Bit 0 is the right sensor and Bit 1 is the left sensor.

Left State means the left sensor detects white surface and right sensor detects black surface, which means car needs to turn left.

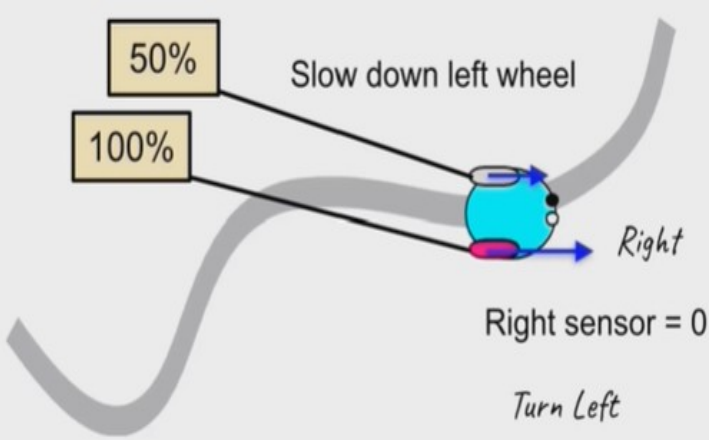
Take Input (L)0,1(R) from Left State. Next state is Center, but same Input from Center State is Left State. Toggling between Center and Left is a way to produce 50% duty cycle from the left wheel to slow it down.

Sensor with 3 State FSM

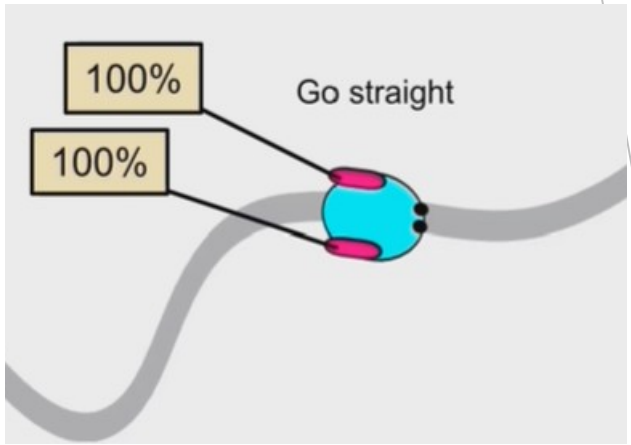
Visualizing Motor Outputs



Right Turn. Left Wheel High, Right Wheel 50% Duty Cycle



Left Turn. Right Wheel High, Left Wheel 50% Duty Cycle



Straight. Both Right and Left Wheel High.

Reference

- 8-Channel QTRX Reflectance Sensor Array: https://www.pololu.com/product/3672