



### Overview:

Students will apply their skill of digital input to detect when a banana is touched to trigger an alarm sound generated by the internal speaker on the TI-Innovator™ Hub. An electronic switch is built using a TTL Power MOSFET, commonly called an FET, with a fresh banana connected to the gate of the transistor. The electronic switch, once built on the breadboard, works just like the mechanical switch used in the related skill builder.

### Goals:

1. Assemble an electronic switch on a breadboard using a field effect transistor (TTL Power MOSFET).
2. Understand how a TTL Power MOSFET can be used in a circuit.
3. Apply the concept of getting digital input on the TI-Innovator Hub.
4. Author a TI-Basic program that polls the state of the digital input on BB1 and plays a tone on the internal speaker when the state of the switch is ON.

### Background:

A Field Effect Transistor (FET) is a device that changes the conductivity of a circuit based on the voltage applied to the device. An FET has three legs named the gate, the source, and the drain. The two legs called the source and drain can be inserted into a circuit to act similarly to a switch controlling the current flow through the circuit. The gate controls the FET like a slide on a switch.

The big difference between a slide switch and the FET is that the FET is controlled by the application of a voltage to the gate, while a finger pushing the slide controls a mechanical switch. FETs are extremely sensitive to voltage changes and require virtually no current. These features make the FET a perfect choice for a banana switch!

In the circuit used for this activity, the banana is connected to the gate of the FET. The banana is charged from the 3.3V pin on the breadboard connector of the TI-Innovator Hub through the 10M Ohm resistor. The charge from the banana connected to the gate closes the source-drain circuit and keeps the FET on. When a well-grounded person touches the banana, the charge on the banana is conducted through the person, and the gate voltage drops to zero. Subsequently, the source and drain circuit is opened, and so the FET turns off. So, when the banana is touched and grounded, the FET is turned off. And when it is not being touched, the FET is turned on.

A feature of the FET is that the gate requires virtually no current, so there is no risk of shock to the person touching the banana and conducting the charge off the banana. In this circuit, a 1KΩ load resistor is placed in the source-drain circuit to produce a voltage drop to zero when the FET is on. When the FET is off, no current flows through the 1KΩ resistor, and there is no voltage drop from 3.3V.

The voltage drop across the load resistor can be monitored using the digital input on BB1. The digital input on the TI-Innovator Hub will report a 1 when it detects 3.3v while a 0 when it detects 0V. Thus, the digital input will return a 1 when the banana is touched because the FET is off and there is no voltage drop from 3.3V. The digital input will return a 0 when the banana is not being touched because the FET is on and there is a voltage drop to 0V.

In this activity, to ground the person well that is touching the banana, they should touch or lean an arm on the square of foil attached to the ground on the TI-Innovator Hub. Again, the current and voltage are so small, there is no risk of shock.

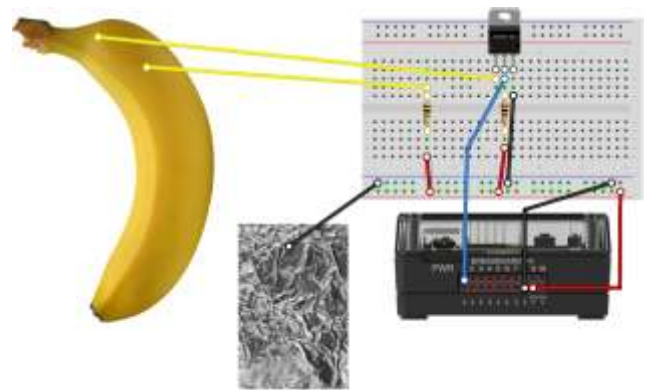


### Materials and Tools:

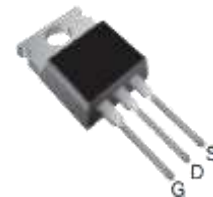
- TI-84 Plus CE
- TI-Innovator™ Hub with USB Cable
- Banana
- Aluminum foil
- Tape
- Scissors
- TI-Innovator Breadboard Pack:
  - Breadboard
  - Male to Male jumper cable
  - Potentiometer with Knob
  - Resistor 1K Ohm (brown, black, red)
  - Resistor 1M Ohm (brown, black, blue)
  - TTL Power MOSFET

### Build the Hardware:

1. Use a red Male to Male Jumper Cable to connect the 3.3V of the TI-Innovator Hub to the red power bus on the breadboard.
2. Use a black Male to Male Jumper Cable to connect the Gnd of the TI-Innovator Hub to the blue ground bus on the breadboard.
3. Insert a TTL Power MOSFET into the middle of the breadboard.
4. Use a black Male to Male Jumper Cable to connect the far right leg (source) to the blue ground bus.
5. Insert a 1K Ohm Resistor into the center TTL Power MOSFET (S).
6. Use a red jumper wire to connect the other end of the 1 KΩ to the red 3.3V bus on the breadboard.
7. Use a blue Male to Male Jumper Cable to connect the center leg (D) to digital input BB1 on the TI-Innovator Hub.
8. Insert a yellow Male to Male Jumper Cable from the far left leg of the TTL Power MOSFET (G) to the banana. Push the jumper wire pin into the banana.
9. Insert a second yellow Male to Male Jumper Cable from the banana back into the breadboard.
10. Insert a 10 MΩ resistor into the same column as the yellow return Male to Male Jumper Cable from the banana.
11. Use a red Male to Male Jumper Cable to connect the 3.3V red power bus to the opposite side of a 10 MΩ resistor.
12. Fold a piece of foil into a 10 cm x 10 cm square and tape the pin of a black jumper wire to the one side of the foil square.
  - Ensure there is a good connection between the metal pin on the Male to Male Jumper Cable and the foil.
13. Insert the other end of the Male to Male Jumper Cable into the blue ground bus on the breadboard.



FET Transistor Led Diagram



G- gate, D- drain, S- sink



#### Write the Software for the TI-84 Plus CE:

**Task:** Write a program that uses digital input to check the state of the FET switch and plays a note on the internal speaker when a person touches the foil with one hand and the banana with the other hand.

When the **banana and foil are touched at the same time**, the FET is off, there is no voltage drop on the 1K $\Omega$  resistor, and the **digital input is equal to 1**.

**When the banana and foil are not being touched**, the FET is on, there is a voltage drop across the 1K $\Omega$  resistor, and the **digital input is equal to 0**.

#### Code for the TI-84 Plus CE:

```
Send("CONNECT DIGITAL.IN 1 TO BB1")
0→S
For(N,1,200)
Send("READ DIGITAL.IN 1")
Get(S)
If S=1
Then
Send("SET SOUND 500 TIME .1")
Disp "ON"
Else
Disp "OFF"
End
Wait (.1)
End
```

#### Extras for Experts:

Connect the speaker from the Unit 1 project to the TI-Innovator Hub and play the alarm tone through the hand-made speaker.

#### Sample Answer:

Hook up the speaker exactly as it was in Project 1. Be sure to connect the speaker to BB 2 on the TI-Innovator Hub with this command.

```
Send "CONNECT SPEAKER 1 TO BB 2"
```

```
Replace Send( "SET SOUND 512 TIME .1")
```

with:

```
Send( "SET SPEAKER 1 512 TIME .1")
```