Input/output pins on the Arduino

ENGR 40M lecture notes — July 14, 2017
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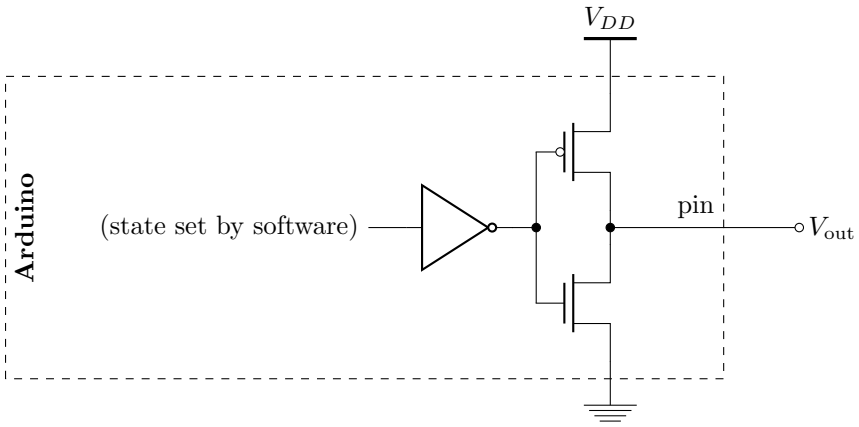
Note: An extended version of this handout is in the spring 2017 notes on the class website.

An *input/output pin*, or *I/O pin*, is the interface between a microcontroller and another circuit. In the Arduino, you configure whether a pin is an input or output using the `pinMode()` function.

Output pins

An output pin provides V_{DD} or 0 V, by making a connection to V_{DD} or ground via a transistor. You set its state to `HIGH` (for V_{DD}) or `LOW` (for 0 V) using the `digitalWrite()` function. A (simplified) schematic of an output pin is shown below. You might notice that it looks a bit like a CMOS inverter (or rather, two).



The transistors in the output pin have non-negligible on resistance, so aren't suitable for driving large loads. When talking about this resistance in relation to an output pin, we call it the *output resistance* of the pin—in other words, the resistance "seen" by a device connected to the pin. Since this resistance might depend on the state of the pin (`HIGH` or `LOW`), it actually has two output resistances. You'll measure both in prelab 2b.

Input pins

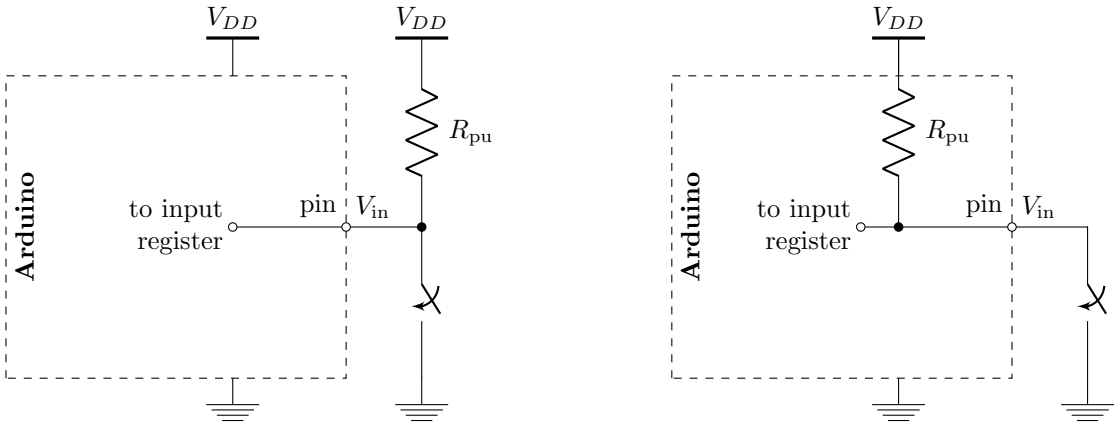
An *input pin* reads the voltage on the pin as if it were a voltmeter, and returns either `HIGH` (`1`) in software if the voltage is close to V_{DD}, or `LOW` (`0`) if it is close to 0 V. An input pin can be read using the `digitalRead()` function.

The value returned by `digitalRead()` is unpredictable (*i.e.*, could be either `HIGH` or `LOW`) when the input voltage is not close to either V_{DD} or 0 V. The precise meaning of "close" varies between microcontrollers, but for the Adafruit Metro Mini[1] in our circuit, the input pin voltage needs to be at least $0.6V_{DD}$ to qualify as `HIGH`, and at most $0.3V_{DD}$ to qualify as `LOW`.

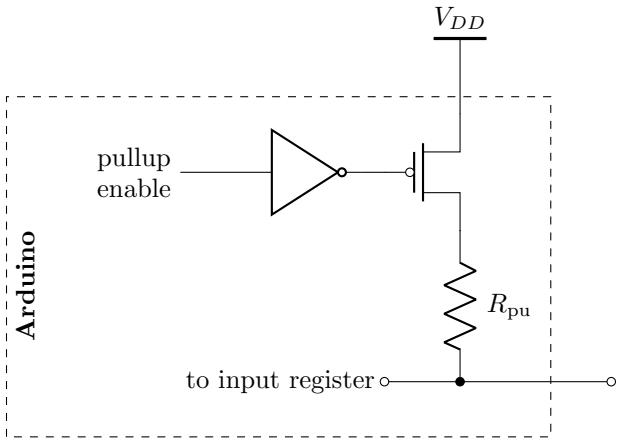
Switches control connections, not voltage, so if we wish to connect a switch to an input pin, we need a (simple) circuit to "convert" the state of the switch to a voltage. A common circuit used to do this is shown below on the left. The resistor R_{pu} is often called a *pull-up resistor*, because its function is to "pull up" the voltage of the pin to V_{DD} when the voltage isn't being *driven* to ground by the closed switch.

[1] Or more precisely, the ATmega328; this information is on page 313 of its datasheet at http://www.atmel.com/images/Atmel-8271-8-bit-AVR-Microcontroller-ATmega48A-48PA-88A-88PA-168A-168PA-328-328P_datasheet_Complete.pdf.

In fact, this pattern is so common that microcontrollers provide *internal pull-up resistors* that you can enable in software by using `pinMode(pin, INPUT_PULLUP)` (where ***pin*** is your pin number). If you do this, then you can connect just a switch, as shown below right.



As you might guess, the internal pull-up resistor itself is enabled using a PMOS transistor. Thus, here is a (simplified) schematic of an input pin:



Quick reference

Note: In your code, we expect you to use sensible variable names and to define constants for pin numbers.

Lines that should go in your `setup()` function:

```
pinMode(pin, INPUT);          // configures pin pin as input without pull-up
pinMode(pin, INPUT_PULLUP);   // configures pin pin as input with pull-up
pinMode(pin, OUTPUT);         // configures pin pin as output
```

Lines that control or read the pins:

```
byte x = digitalRead(pin);    // reads the value of pin pin
digitalWrite(pin, HIGH);      // sets the state of pin pin to HIGH
digitalWrite(pin, LOW);       // sets the state of pin pin to LOW
```