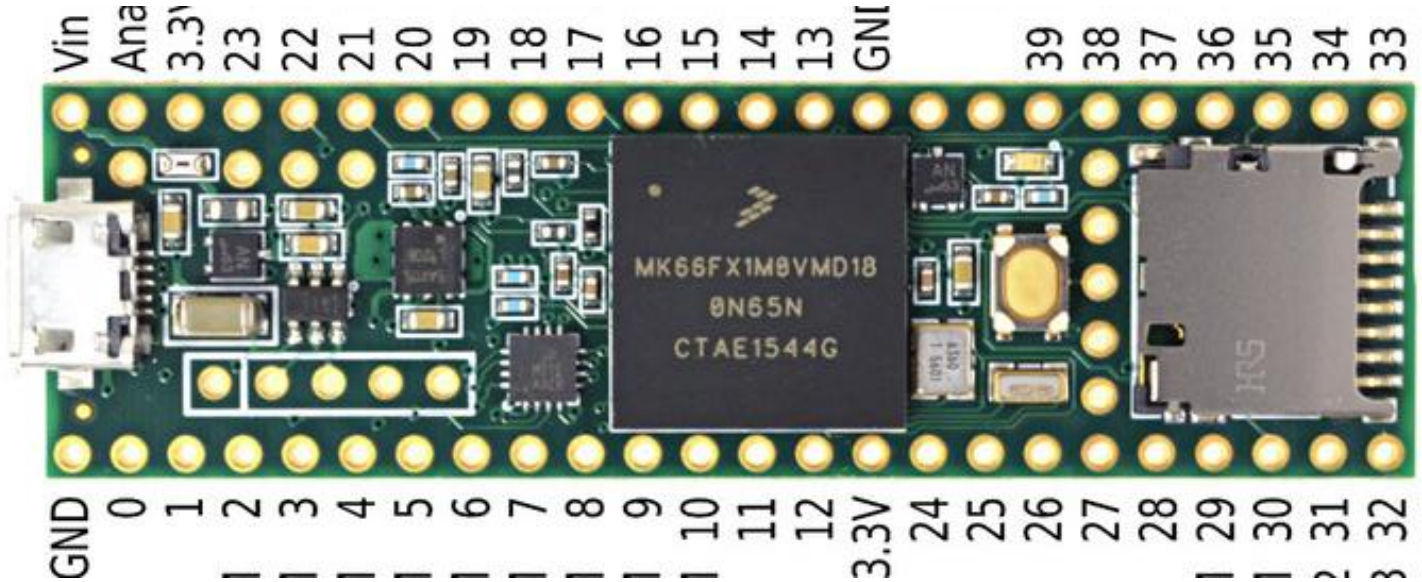
Manipulating Pins on the Teensy 3.5



Data Types

- short, int, long: size depends on the particular microprocessor
- In order to be clear about sizes, gcc (our compiler) provides a set of types, including:
  - int8_t 8-bit signed
  - uint16_t 16-bit unsigned
  - uint32_t 32-bit unsigned

  - Use these for our projects – not short, int, long

Teensy 3.5

				GND				Vin (3.6 to 6.0 volts)					
Touch	MOSI1	RX1		0				Analog GND					
Touch	MISO1	TX1		1				3.3V (250 mA max)					
			PWM	2				23	A9	PWM			Touch
SCL2	CAN0TX		PWM	3				22	A8	PWM			Touch
SDA2	CAN0RX		PWM	4				21	A7	PWM	CS0	mosi1	
	miso1	tx1	PWM	5				20	A6	PWM	CS0	sck1	
			PWM	6				19	A5			SCL0	Touch
scl0	mosi0	RX3	PWM	7				18	A4			SDA0	Touch
sda0	miso0	TX3	PWM	8				17	A3			sda0	Touch
	CS0	RX2	PWM	9				16	A2			scl0	Touch
	CS0	TX2	PWM	10				15	A1		CS0		Touch
	MOSI0			11				14	A0	PWM	sck0		
	MISO0			12				13	(LED)		SCK0		
				3.3V				GND					
				24					A22	DAC1			
				25					A21	DAC0			
			tx1	26				39	A20				
			rx1	27				38	A19	PWM		SDA1	
				28				37	A18	PWM		SCL1	
Touch	can0tx		PWM	29				36	A17	PWM			
Touch	can0rx		PWM	30				35	A16	PWM			
	CS1	RX4	A12	31				34	A15		CAN1RX	sda0	
	SCK1	TX4	A13	32				33	A14		CAN1TX	scl0	

Teensy 3.5

- Floating Point Unit (FPU): high-speed math
- Serial I/O: RS232, I2C, SPI, CAN, Ethernet
- Digital I/O
- Pulse Width Modulation (PWM)
- Multiple timers
- Digital-to-analog converter channels (2)
- Analog-to-digital converter channels (25)

Digital Input/Output

The Teensy encodes a digital value using 0V (low) and 3.3V (high)

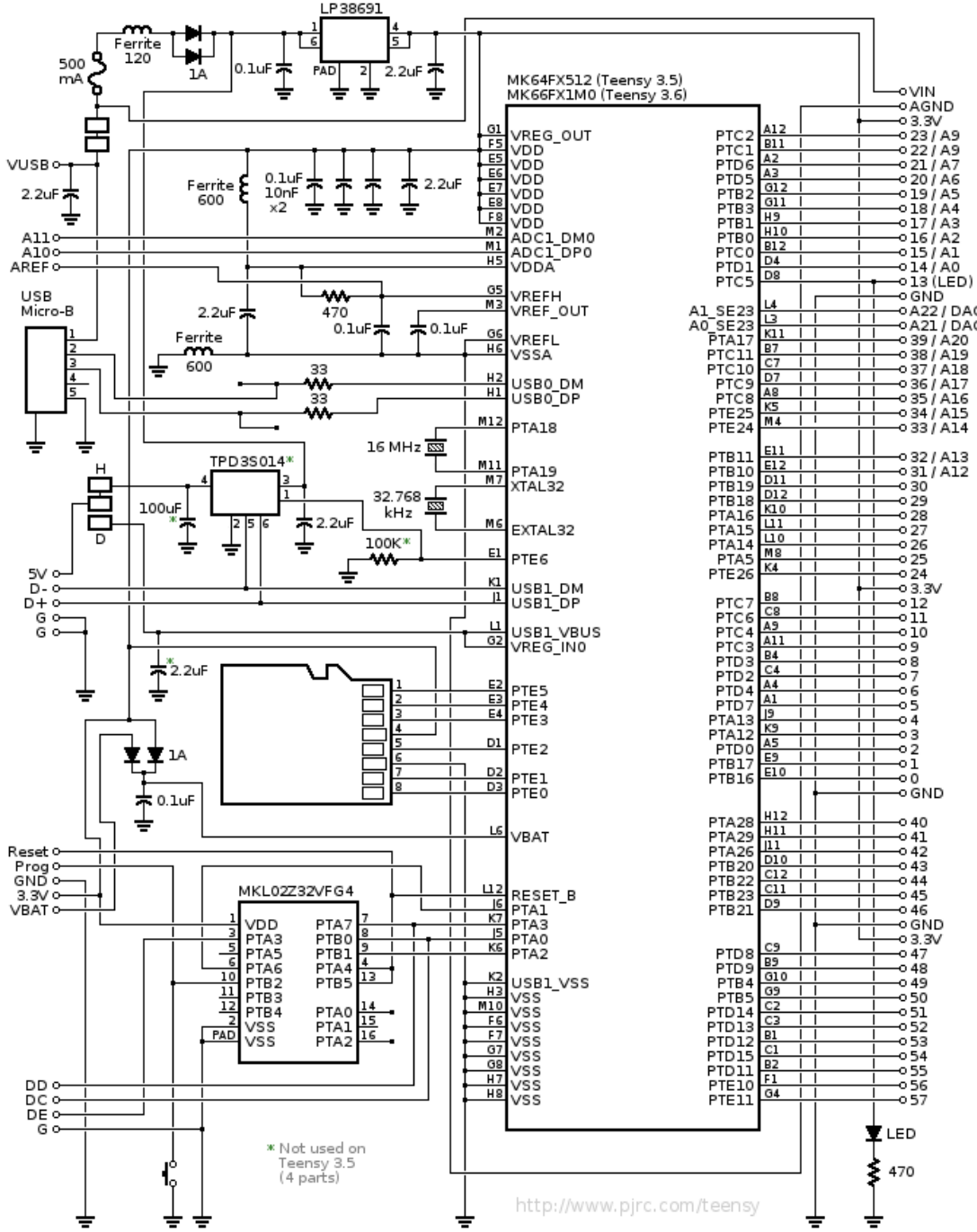
- If a pin is an input:
  - We can ask the pin what its voltage state is
  - Possible answers: 0 or 1 (low or high)
- If a pin is an output:
  - We can drive the pin to be 0V or 3.3V
  - Again, these are encoded digitally as 0 or 1

Digital Input/Output

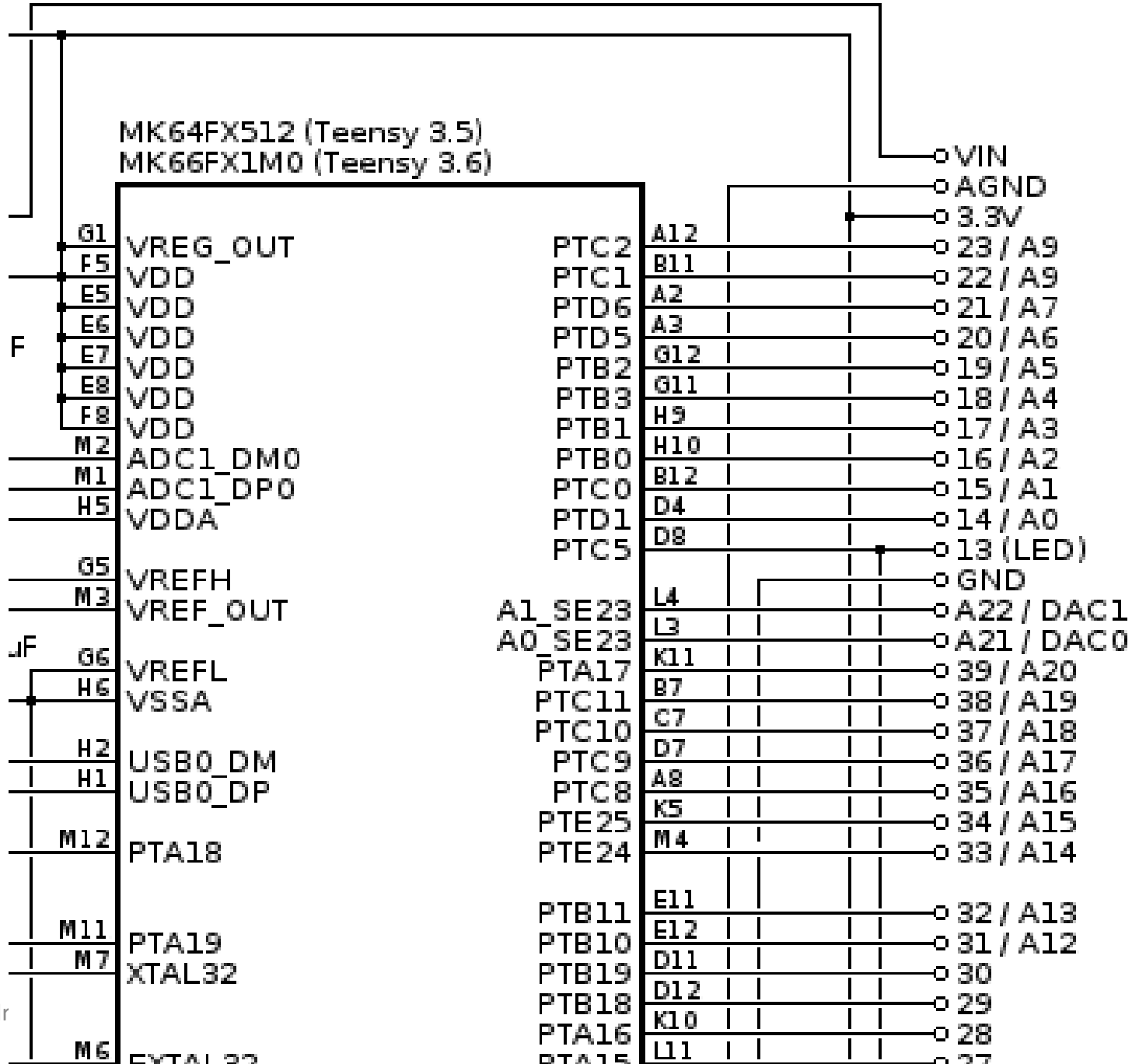
- Pins are organized into groups, called *PORTS*
- Each port can be composed of up to 32 pins
  - In practice, this number is generally much smaller
- The ports are named A … E

Teensy 3.5 Schematic

Key take-away: shows us the connection between the Teensy pin numbers and the Arm Cortex M4 I/O ports

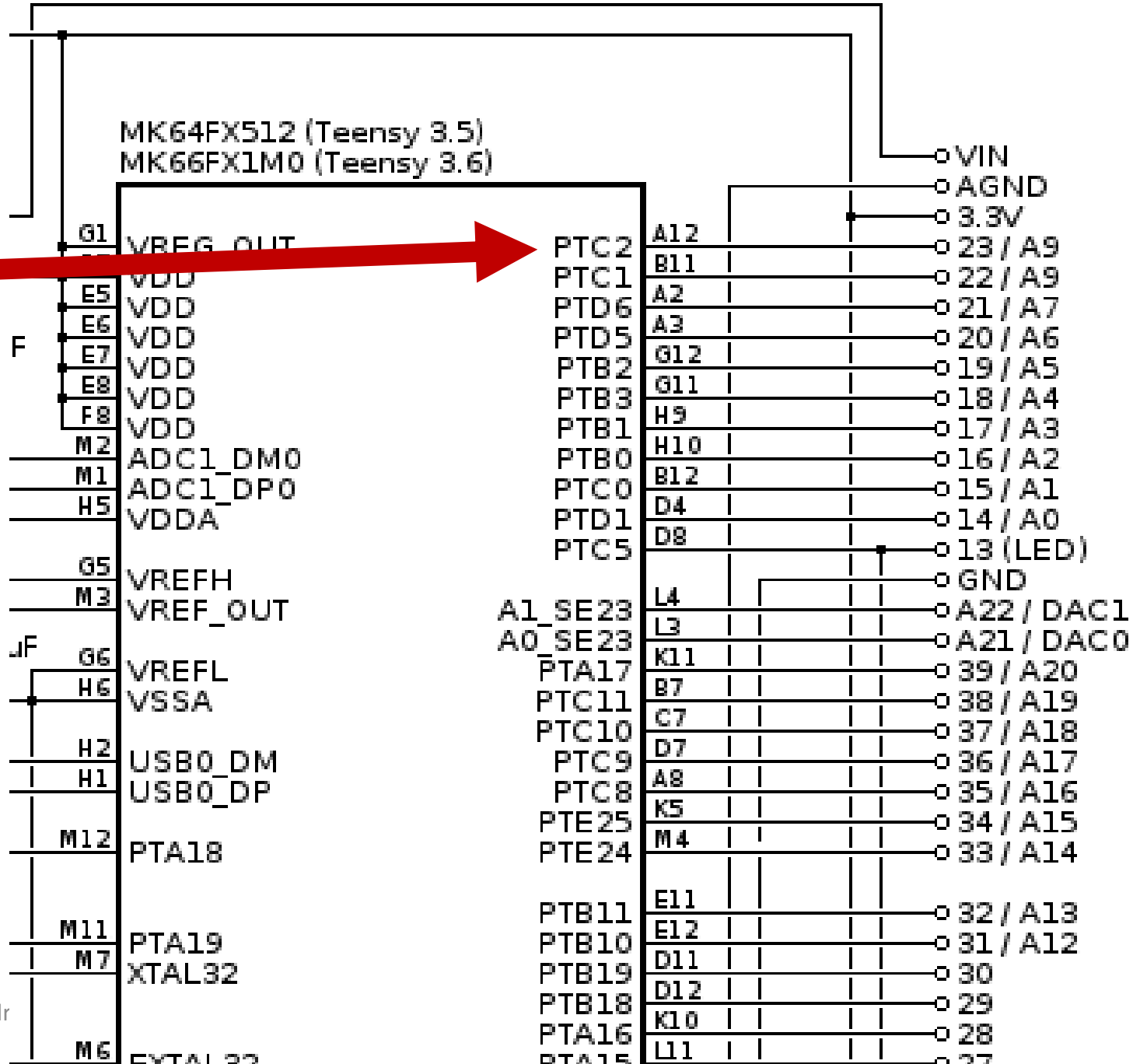


Teensy 3.5 Schematic



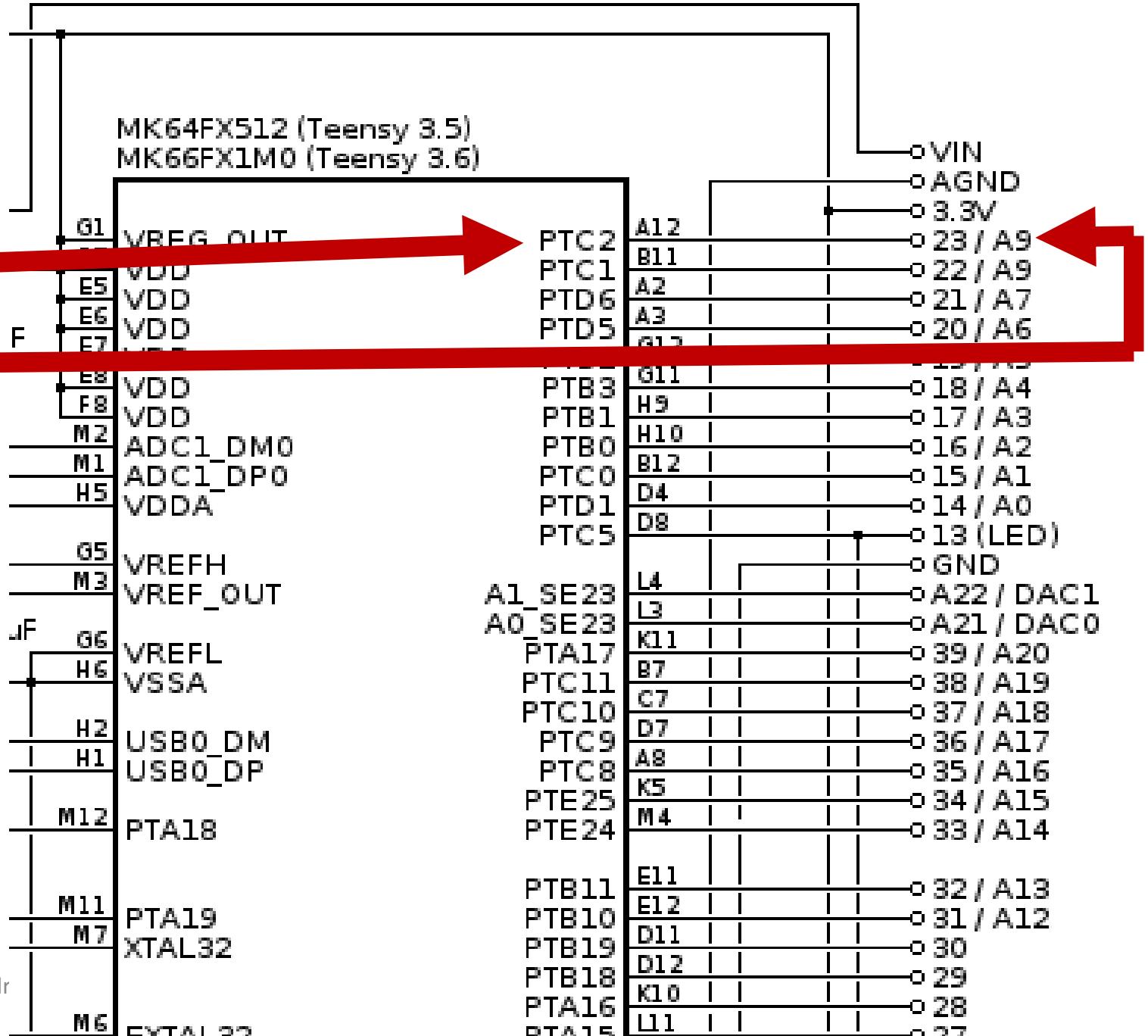
Teensy 3.5 Schematic

- Port C, bit 2



Teensy 3.5 Schematic

- Port C, bit 2
- Teensy pin 23
  - Also analog pin 9



Pins in the Arm Cortex M4

- Most pins have multiple possible functions
  - Can be a digital input or output
  - Some can generate a continuous voltage (analog output)
  - Many can read a continuous voltage (analog input)
  - Communication

Configuring a Pin for Digital Output

There is an on-board LED connected to PORT C, bit 5: let’s write code to blink the LED

Configuring a Pin for Digital Output

There is an on-board LED connected to PORT C, bit 5: let's write code to blink the LED

- Initialization:

```
// Initialize PORT C, bit 5 to be a digital I/O bit
PORTC_PCR5 = PORT_PCR_MUX(0x1);
```

- PORTC_PCR5 is a special-purpose register (32 bits) that controls what this specific pin does
- PCR = Port Configuration Register

Configuring a Pin for Digital Output

- Initialization, step 2:

```
// Configure bit 5 to be an output (and leave all others as inputs)
GPIOC_PDDR |= 0x20;
```

- GPIO = General Purpose Input/Output
- PDDR = Port Data Direction Register

- On boot: all pins are configured as inputs

Setting to Pin into the High State

```
// Turn on the bit (and all others unchanged)
GPIOC_PDOR |= 0x20;
```

- The pin is now in a high state
- PDOR = Port Data Output Register

Putting it Together in the Arduino Environment

This function is called when the processor first boots:

```
void setup() {
  // Configure PORTC, bit 5 to be a digital I/O bit
  PORTC_PCR5 = PORT_PCR_MUX(0x1);

  // Configure bit 5 to be an output (and leave all others as inputs)
  GPIOC_PDDR |= 0x20;
}
```

Putting it Together in the Arduino Environment

And this function is called repeatedly thereafter:

```
void loop() {
  // Turn on the bit
  GPIOC_PDOR |= 0x20;

  // Wait for 0.1 second
  delay(100);

  // Turn off the bit (and all others)
  GPIOC_PDOR &= ~0x20;

  // Wait for 0.1 second
  delay(100);
}
```

Arduino Environment

The environment automatically includes the following function:

```
void main() {
    setup();

    while(1)
    {
        loop();
    }
}
```

An Alternative Implementation

```
void loop() {
  //
  GPIOC_PDOR ^= 0x20;

  // Wait for 0.1 second
  delay(100);
}
```

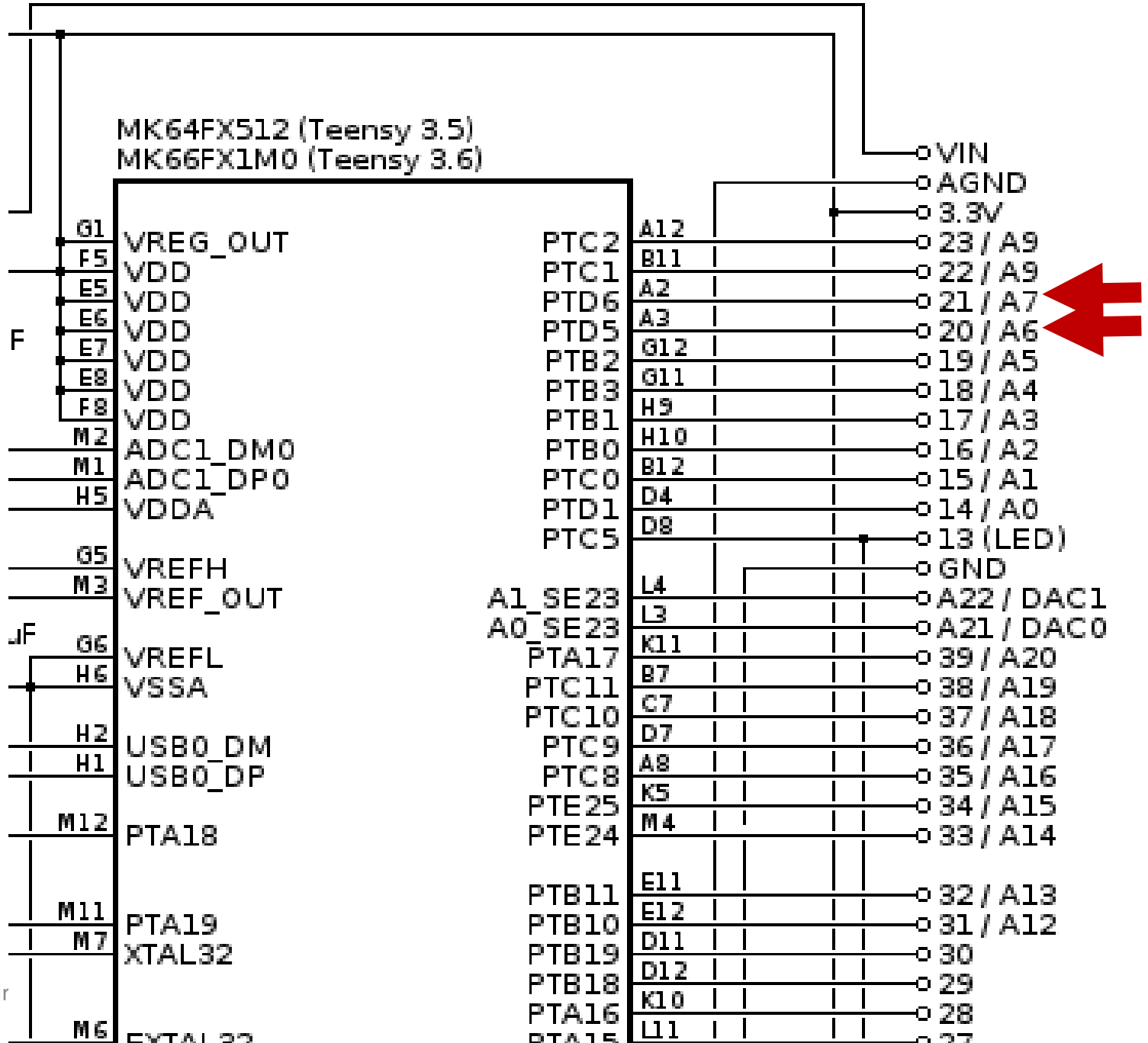
PORTS A .. E

- PORTx_PCRy = each bit has one register
- GPIOx_PDDR, GPIOx_PDOR: each port has one register

- Note: the Arduino environment provides other ways to manipulate these pins (don't use these alternatives!)
  - For digital I/O, we will use these registers. We get:
    - Efficiency
    - Simultaneous state change of multiple pins

Teensy 3.5 Schematic

- Let's connect LEDs to PTD5 & 6
- Don't forget the resistor!



Initialization

```
void setup() {
  // Configure PORTD, pins 5 & 6 as digital I/O
  PORTD_PCR5 = PORT_PCR_MUX(0x1);
  PORTD_PCR6 = PORT_PCR_MUX(0x1);


  // Configure bit 5 & 6 to be outputs
  GPIOD_PDDR |= 0x60;
}
```

What does this program do?

```
void loop() {
 GPIOD_PDOR = (GPIOD_PDOR & ~0x60) | 0x60;
 delay(250);
 GPIOD_PDOR = (GPIOD_PDOR & ~0x60) | 0x20;
 delay(250);
 GPIOD_PDOR = (GPIOD_PDOR & ~0x60) | 0x40;
 delay(250);
 GPIOD_PDOR = (GPIOD_PDOR & ~0x60) | 0x0;
 delay(250);
}
```

What does this program do?

```
void loop() {
 GPIOD_PDOR = (GPIOD_PDOR & ~0x60) | 0x60;
 delay(250);
 GPIOD_PDOR = (GPIOD_PDOR & ~0x60) | 0x20;
 delay(250);
 GPIOD_PDOR = (GPIOD_PDOR & ~0x60) | 0x40;
 delay(250);
 GPIOD_PDOR = (GPIOD_PDOR & ~0x60) | 0x0;
 delay(250);
}
```

Flashes LED on PD6 at 2 Hz

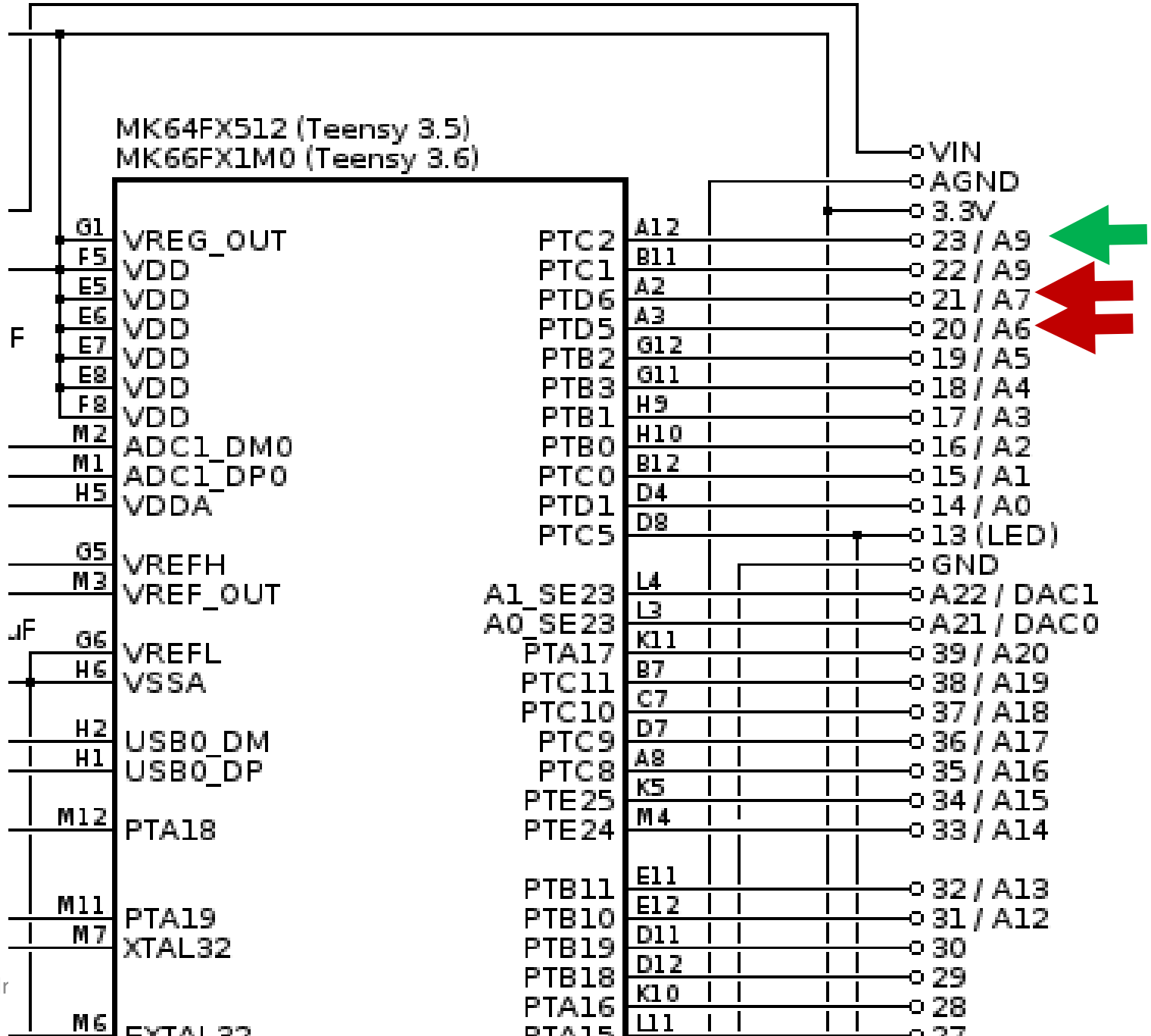
on PD5: 1 Hz

Duty Cycle for each: 50%

Teensy 3.5 Schematic

- Let's connect a switch to PTC2
- Don't forget the pull-up resistor!

- If switch reads zero, turn PTD6 on and PTD5 off
- Otherwise, turn PTD6 off and PTD5 on



Input Register

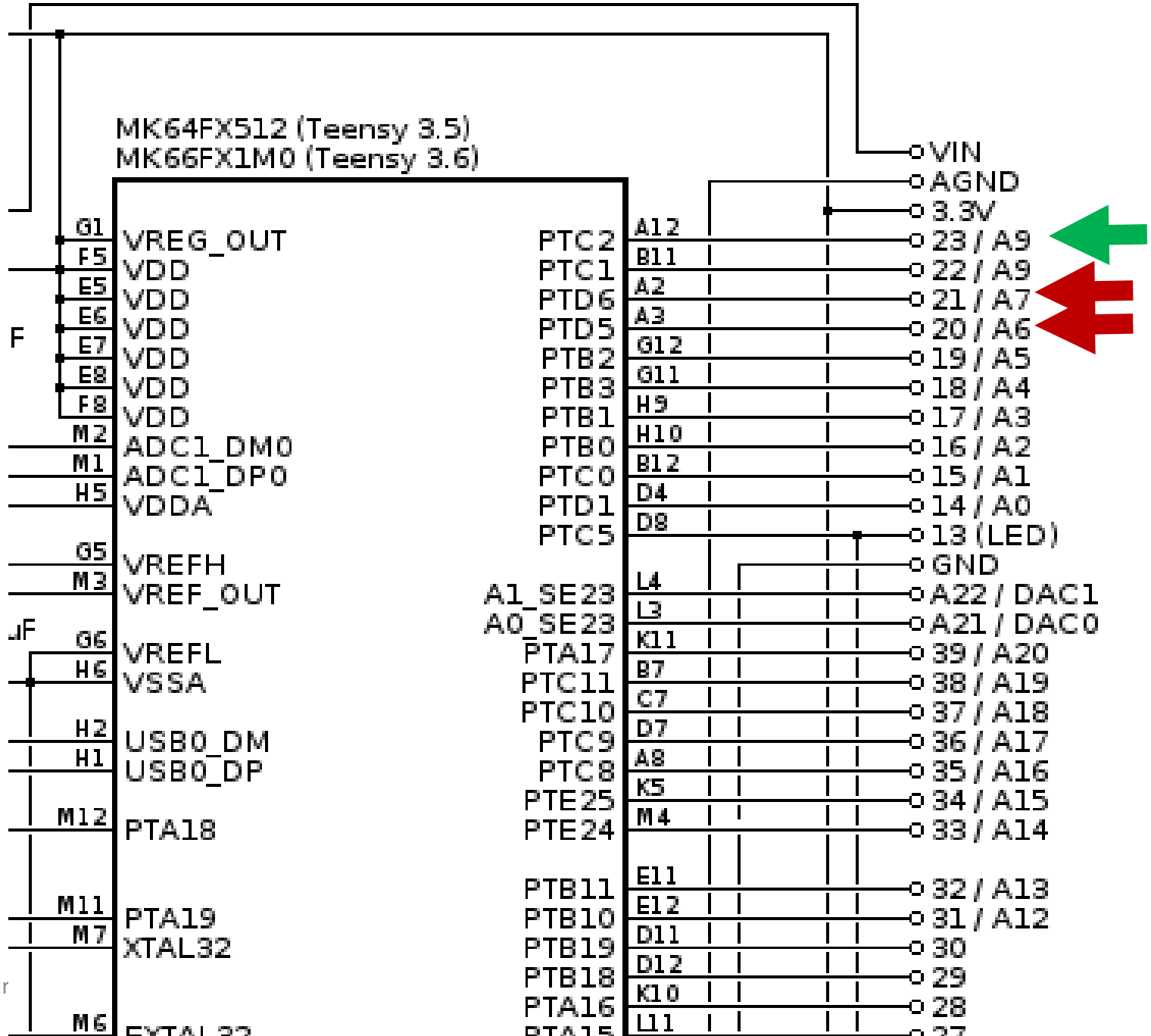
GPIOx_PDIR: Port Data Input Register

- Reading this register will tell us the Boolean state of all pins connected to this register
  - 1 -> ~3.3 V
  - 0 -> 0 V

Teensy 3.5 Schematic

- Let's connect a switch to PTC2
- Don't forget the pull-up resistor!

- If switch reads zero, turn PTD6 on and PTD5 off
- Otherwise, turn PTD6 off and PTD5 on



Initialization

```
void setup() {
  // Configure PORTD, pins 5 & 6 as digital I/O
  PORTD_PCR5 = PORT_PCR_MUX(0x1);
  PORTD_PCR6 = PORT_PCR_MUX(0x1);

  // Configure PORTC, pin 2 as digital I/O
  PORTC_PCR2 = PORT_PCR_MUX(0x1);

  // Configure bit 5 & 6 to be outputs
  GPIOD_PDDR |= 0x60;
}
```

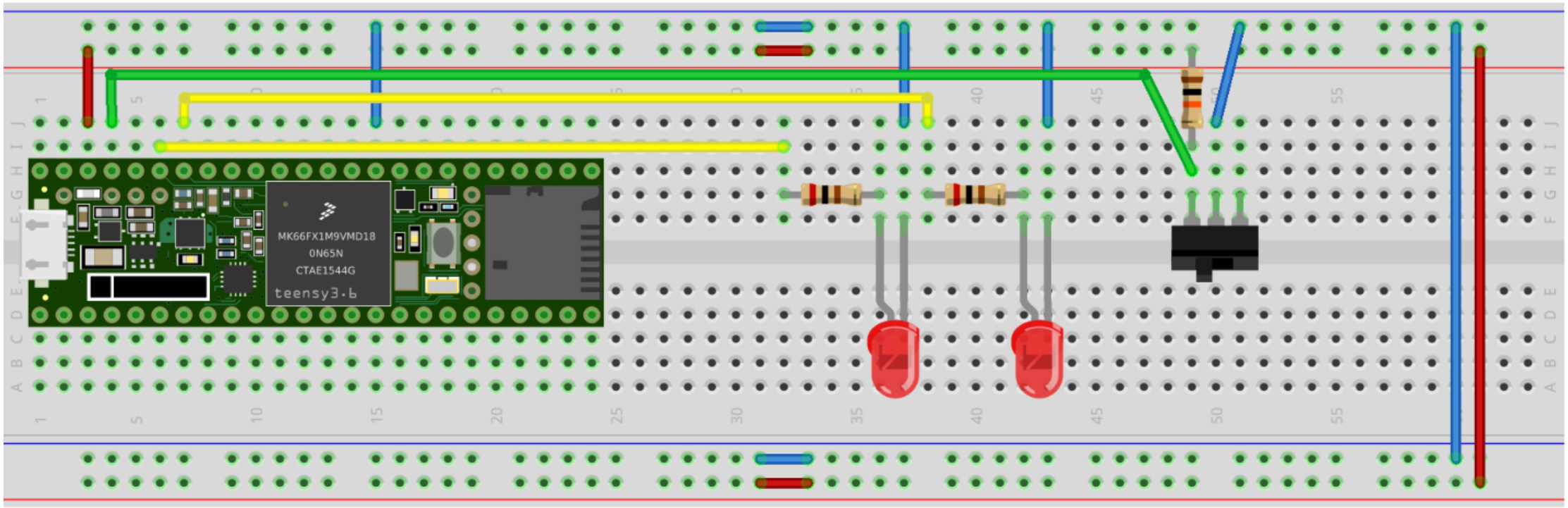
Loop Implementation

```
void loop() {
	if(GPIOC_PDIR & 0x4)
	{
		// Switch open
		GPIOD_PDOR = …
	}else{
		// Switch closed
		GPIOD_PDOR = …

	}
}
```

Loop Implementation

```
void loop() {
	if(GPIOC_PDIR & 0x4)
	{
		// Switch open
		GPIOD_PDOR = (GPIOD_PDOR & ~0x60) | 0x40;
	}else{
		// Switch closed
		GPIOD_PDOR = (GPIOD_PDOR & ~0x60) | 0x20;

	}
}
```

Two LEDS + One Switch



Two LEDS + One Switch