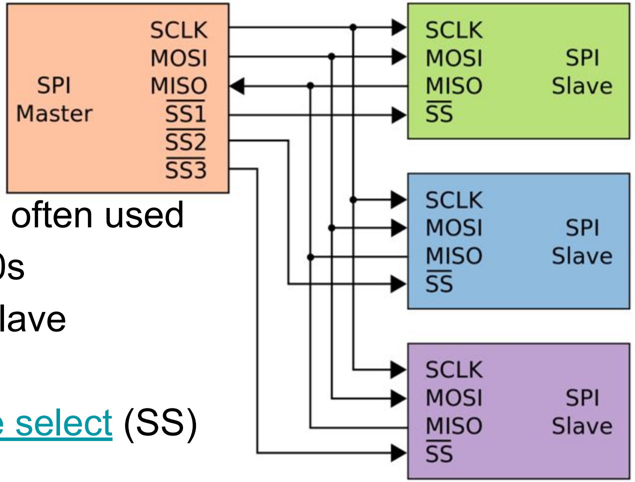
Project 6

Hints

Important lessons to take away from Project 6

- P6 will build off of P2b in that we will drive 2 servo motors (albeit in a totally different fashion...as a game), and use more of the DISCOVERY board.
- In industry, complex systems involve much more that just a microcontroller.
    - Our DISCOVERY board integrates many devices including an LCD, 2 LEDs, a pushbutton, a joystick, an audio DAC, MEMS devices (Microphone, 3 axis gyroscope,...) and more.
- We will monitor the angle of the DISCOVERY board using the L3GD20 gyro
- We will process (filter, integrate) gyro data in real time.
- We will talk to the L3GD20 over the SPI bus
- Vendors often provide Board Support Packages (BSP) to help embedded developers. We will use more of the BSP for DISCOVERY.

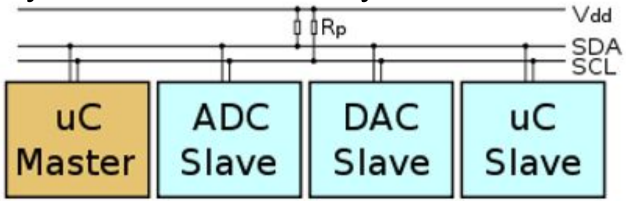
SPI - Serial Peripheral Interface



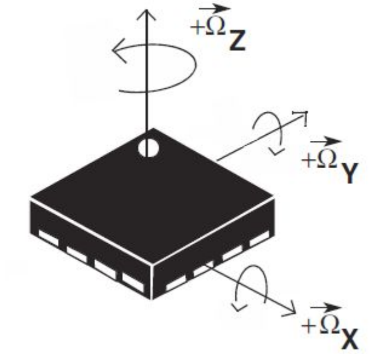
- **SPI** is a 4-wire synchronous serial communication specification often used in embedded systems. Developed by Motorola in the mid-1980s
- SPI devices communicate in full duplex mode using a master-slave architecture with a single master.
- Multiple slave-devices are supported, each with their own slave select (SS)
- The SPI bus specifies four logic signals:
  - SCLK: Serial Clock (output from master)
  - MOSI: Master Output Slave Input, or Master Out Slave In (data output from master)
  - MISO: Master Input Slave Output, or Master In Slave Out (data output from slave)
  - SS: Slave Select (often active low, output from master). Also known as CS (chip select)
- Beware! SPI has are different modes related to clock polarity and rising/falling edge.
- SPI may operate up to 10Mbps (in full duplex)!
- SPI may be wired to operate in a 3-wire fashion. (e.g. the compass on DISCOVERY)
- STM DISCOVERY uses SPI to connect to a gyro

I2C Bus (Inter-Integrated Circuit Bus)

- A serial protocol for two-wire interface to connect low-speed devices like microcontrollers, EEPROMs, A/D and D/A converters in embedded systems.
- Invented in 1980s by Philips (now NXP) and it is used by almost all major IC manufacturers.
- Appropriate where simplicity (2 bidirectional wires) and low cost are more important than speed
  - Serial DAta Line (SDA) and
  - Serial CLock Line (SCL)
- I²C reference design has a 7-bit address space, with a rarely-used 10-bit extension
- I2C can run at different speeds:
  - (400 kbit/s *Fast mode*, 1 Mbit/s *Fast mode plus* or Fm+, and 3.4 Mbit/s *High Speed mode*).
- A single I2C bus can support many devices
  a. A master node generates the clock and initiates communication with slaves.
  b. A slave node has a unique (7-bit) address, and responds only when addressed by the master.
  c. I2C is a multi-master bus protocol , which means that any number of master nodes can be present.



MEMS gyroscope - L3GD20



A MEMS (MicroElectroMechanical System) gyro is a small, inexpensive sensor that measures angular velocity. Gyro - not an accelerometer

The units of angular velocity are measured in degrees per second
The L3GD20 has a full scale of ±250/±500/ ±2000 dps, with user-selectable bandwidth.

An angular **rate gyroscope** produces a positive-going digital output for counter-clockwise rotation around the sensitive axis considered.

Talks to the external world through a I2C/SPI digital interface. Slave ADdress (SAD) associated with the L3GD20 is 110101xb.

Sensitivity - the gain of the sensor can be determined by applying a defined angular velocity to it. Zero-rate level - the actual output signal if there is no angular rate present.

Board Support Packages (BSP)

The **BSP,** often provided by the board manufacturer, consists of layers of software containing hardware-specific drivers and other routines to provide high-level functionality in a particular hardware environment (the board)

STM provides this for their development boards (e.g. DISCOVERY). We can tailor the specific BSP components for our project using CubeMX in the Middleware and Additional Software tab. STM provides

- Operating system - FreeRTOS or other
- Device drivers / applications - FATFS, networking, FTP, Telnet, etc.
- Support for board components - DISCOVERY has support for gyroscope
    - Gyro device may connect over I2C or SPI, the board uses SPI
    - Cube lets us pick the protocol (may not be DISCOVERY board), and then uses existing HAL SPI/I2C drivers
    - The Additional Software has device specific methods (Gyro method examples)

How do we add Additional Software for our project

stm32l476g_discovery_gyroscope.h

```
/* Sensor Configuration Functions */
uint8_t BSP_GYRO_Init(void);
void  BSP_GYRO_DeInit(void);
void  BSP_GYRO_Reset(void);
uint8_t BSP_GYRO_ReadID(void);
void  BSP_GYRO_GetXYZ(float *pfData);
```

… and more

```
typedef struct
{
  uint8_t Power_Mode;                    /* Power-down/Sleep/Normal Mode */
  uint8_t Output_DataRate;               /* OUT data rate */
  uint8_t Axes_Enable;                   /* Axes enable */
  uint8_t Band_Width;                    /* Bandwidth selection */
  uint8_t BlockData_Update;              /* Block Data Update */
  uint8_t Endianness;                    /* Endian Data selection */
  uint8_t Full_Scale;                    /* Full Scale selection */
} GYRO_InitTypeDef;
```

l3gd20.h

```
/* Sensor Configuration Functions */
void  L3GD20_Init(uint16_t InitStruct);
void  L3GD20_LowPower(uint16_t InitStruct);
uint8_t L3GD20_ReadID(void);
void  L3GD20_RebootCmd(void);

/* High Pass Filter Configuration Functions */
void  L3GD20_FilterConfig(uint8_t FilterStruct);
void  L3GD20_FilterCmd(uint8_t HighPassFilterState);
void  L3GD20_ReadXYZAngRate(float *pfData);
uint8_t L3GD20_GetDataStatus(void);

/* Gyroscope IO functions */
void  GYRO_IO_Init(void);
void  GYRO_IO_DeInit(void);
void  GYRO_IO_Write(uint8_t *pBuffer, uint8_t WriteAddr, uint16_t NumByteToWrite);
void  GYRO_IO_Read(uint8_t *pBuffer, uint8_t ReadAddr, uint16_t NumByteToRead);
```

… and more

Real-time data processing

Large systems often process data in a separate batch process (distinct from data input and output). Example: payroll and billing systems.

Embedded systems often must process data in real time in a continuous fashion. Example: electrocardiograms to look for heart rate or arrhythmia.

Captured data is often “dirty” and must be “cleaned up” as part the processing.
Example: remove mother HR from fetal HR in fetal heart rate detection
Example: MEMS gyro device (what are noise sources...leads to how to remove)

How to remove MEMS gyro noise, condition for our use (convert angular rate into angle through integration).