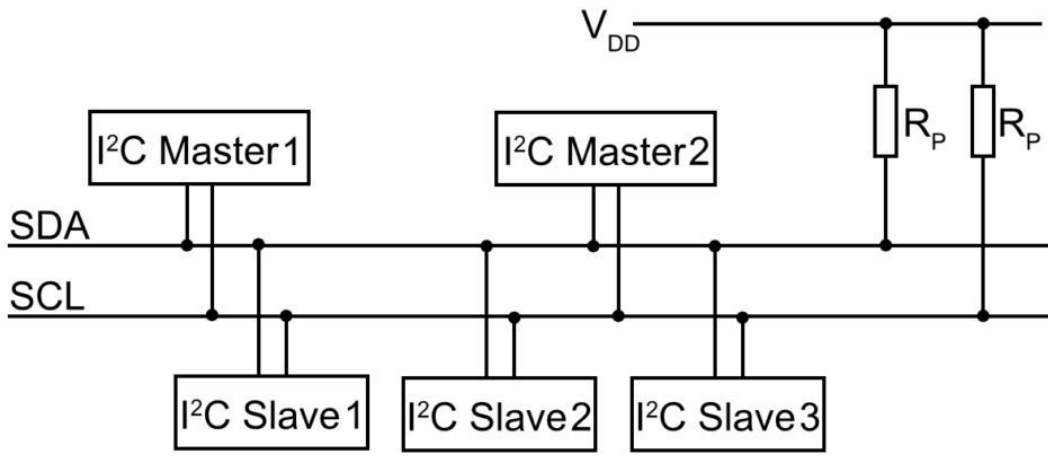
Synchronous Serial Communication

Communication Protocols

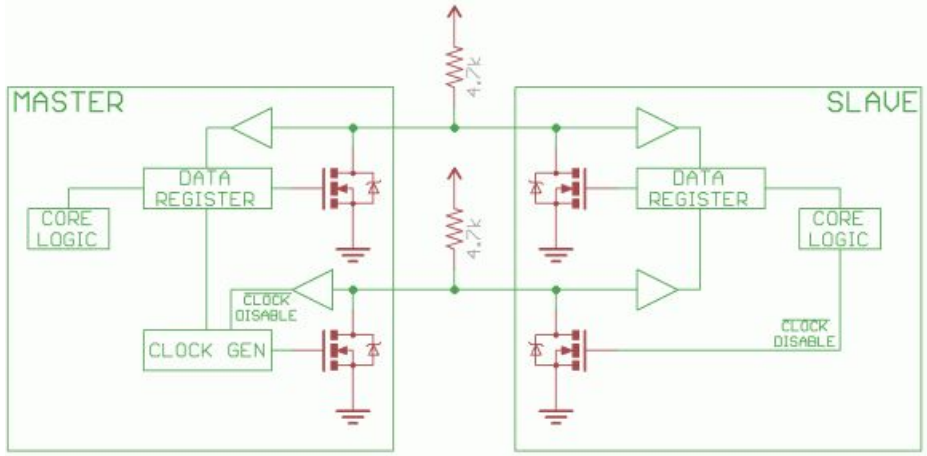
Synchronous Serial Communication (I^2C)

- Inter-Integrated Circuit (**I^2C**)
  - A synchronous serial communication protocol
  - Allows multiple slaves to communicate with one or more masters
  - Is used in short-distance communications
  - Uses two signal lines
    - **SCL**: Serial Clock which is always generated by the current master
    - **SDA**: Serial Data
  - Supports half-duplex communication
  - Speed: upto 3.4 mbps, typically 400 kbps
  - Drivers of the lines are **open drain**
    - They can only pull the signal line low
    - Pull-up resistors are required (1-10 kΩ)



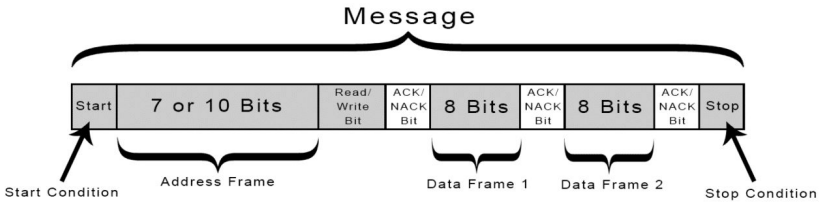
Synchronous Serial Communication (I^2C - Signal Levels)

- I2C supply voltage, typically ranging from 1.2 V to 5.5 V
- Flexibility in connecting devices with different voltage levels
  - Because the devices on the bus don't drive the signals high
  - The pull-up resistors are connected to the lower voltage
  - E.g. a 5V master and a 3.3V slave (pull-up resistors should be connected to 3.3V)
  - If the voltage difference is too great, a level shifter is required
- For short distances, use 4.7 kΩ pull-up resistors and for long distances, or systems with lots of devices, use smaller resistors
- Note that slaves can disable the master clock



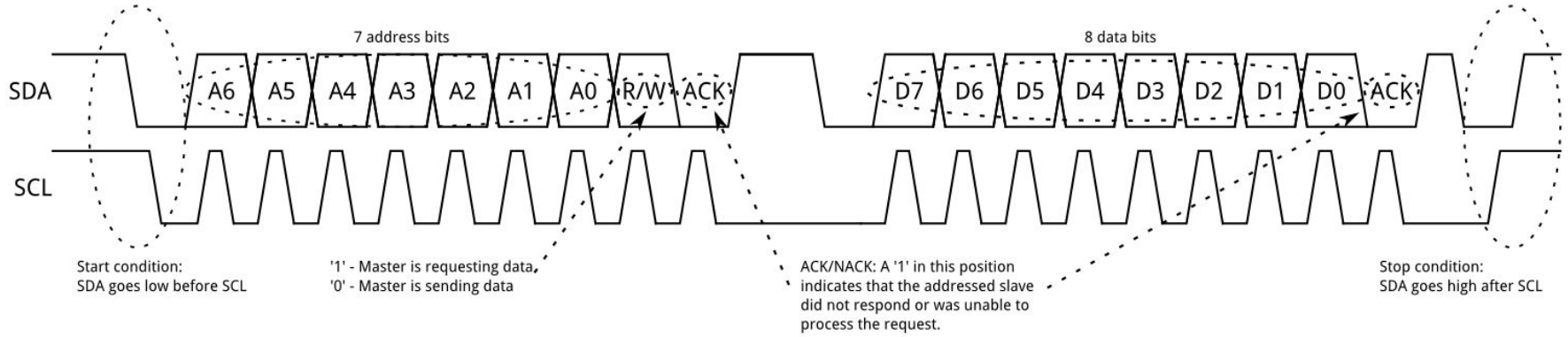
Synchronous Serial Communication (I^2C - Message)

- A message has two types of frame:
  - An **address frame** which is the **unique address** of the slave
    - I^2C can support up to 112 slaves in the 7 bits and 1008 slaves in the 10 bits addressing
    - 16 addresses are reserved (1111 XXX and 0000 XXX)
  - One or more **data frames**: 8-bit data messages passed from master to slave or vice versa.
- Every message is started with the **Start Condition**, then
  - Followed by the **Address Frame**, then
  - The **Read/Write** bit (1: read and 0: write) indicating the operation, then
  - The **NACK/ACK** bit (1: NACk, 0: ACK), then
  - The data frames followed by the NACK/ACK bit and
  - The **Stop Condition**
- The ACK is sent by the receiver for all frames (data or address)



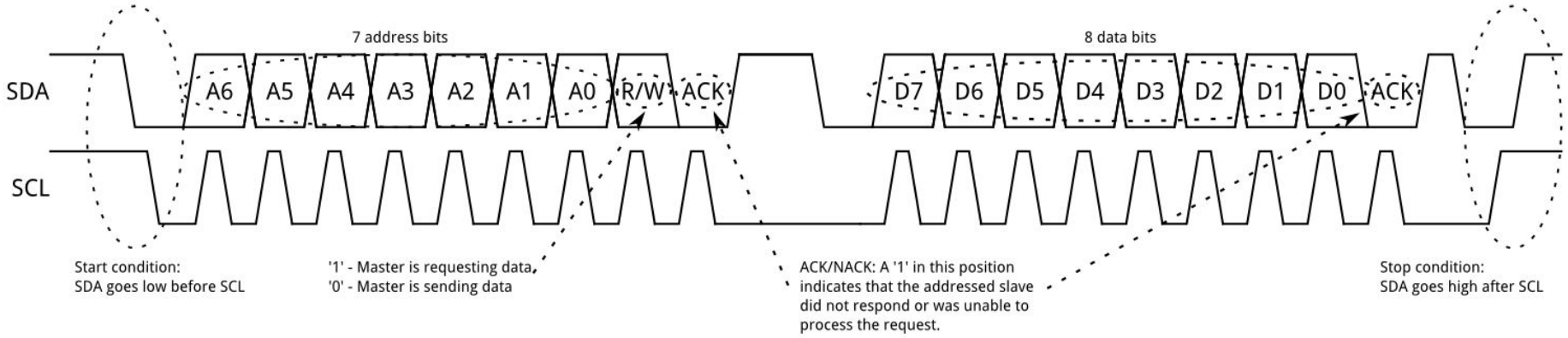
Synchronous Serial Communication (I^2C - Signaling)

- Start Condition
  - The master leaves SCL high and pulls SDA low.
    - This puts all slave devices on notice that a transmission is about to start.
  - If several masters want to take ownership of the bus in the same time
    - The one who pulls SDA low first, takes control of the bus
  - It is possible to have repeated starts
    - Initiating a new communication sequence without losing control of the bus

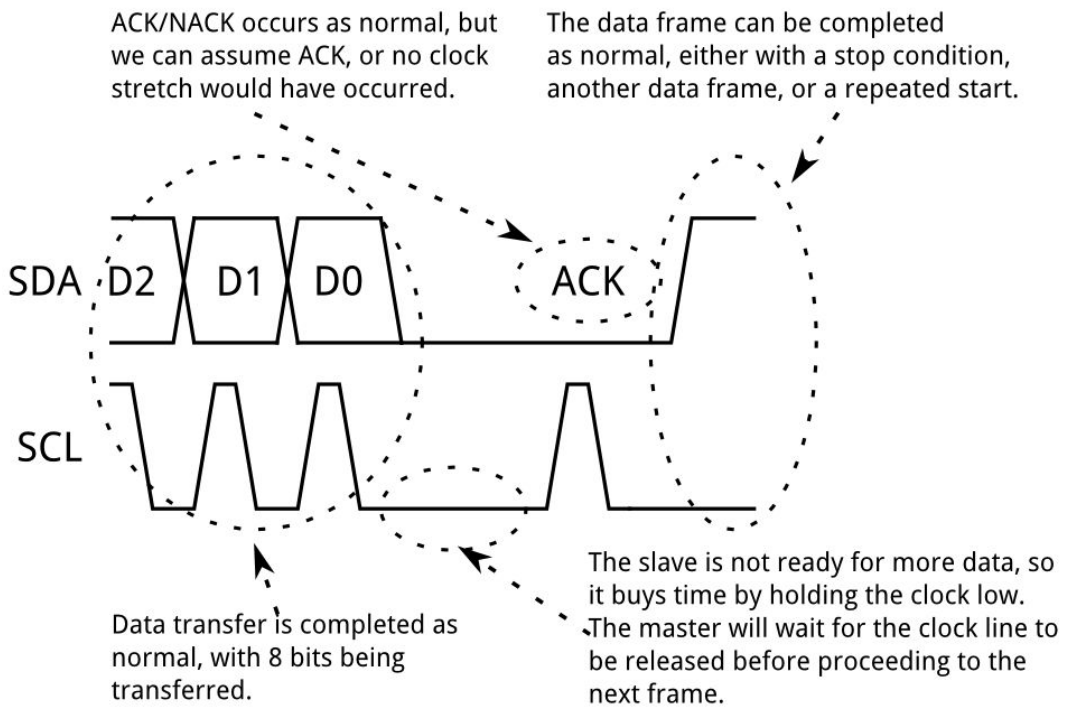


Synchronous Serial Communication (I^2C - Signaling)

- Data is placed on the SDA after SCL goes low, and is sampled after the SCL goes high
  - All changes on data line is done during clock low, except **Start** and **Stop** Conditions
- The most significant bit (MSB) of every frame (address and data) is sent first
- The receiver after receiving every frame, acknowledges the frame by pulling the SDA low
- Stop condition
  - Once all the data frames have been sent, the **master** will generate a stop condition
  - Is a **low to high** transition on SDA after a **low to high** transition on SCL, with SCL remaining high.

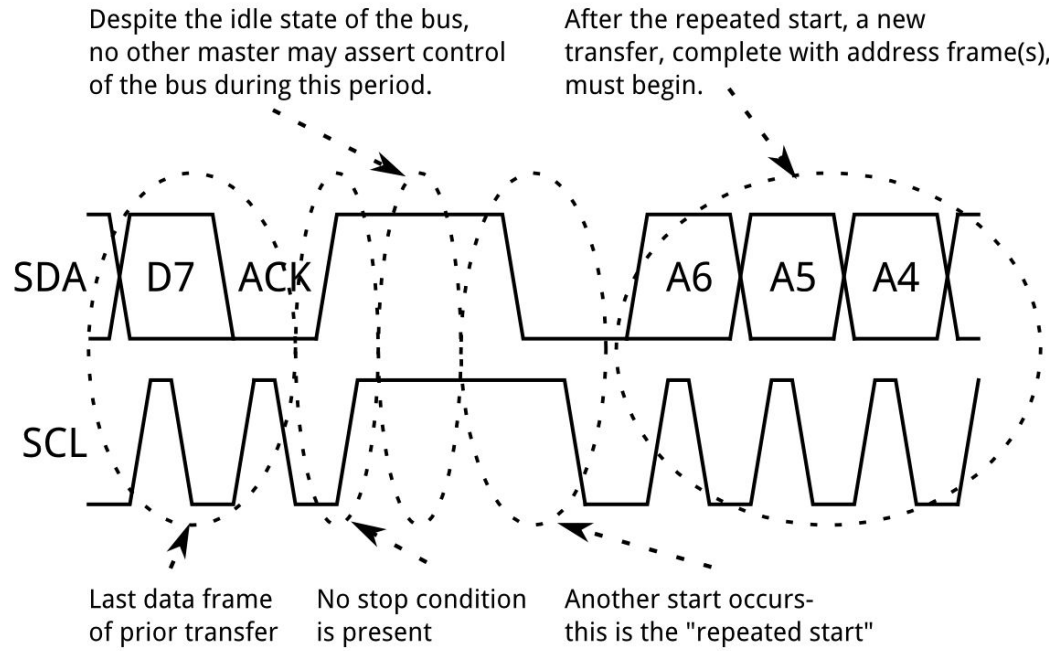


Synchronous Serial Communication (I^2C - Signaling)



Clock Stretching

It is used when the master's data rate will exceed the slave's ability to process the data.

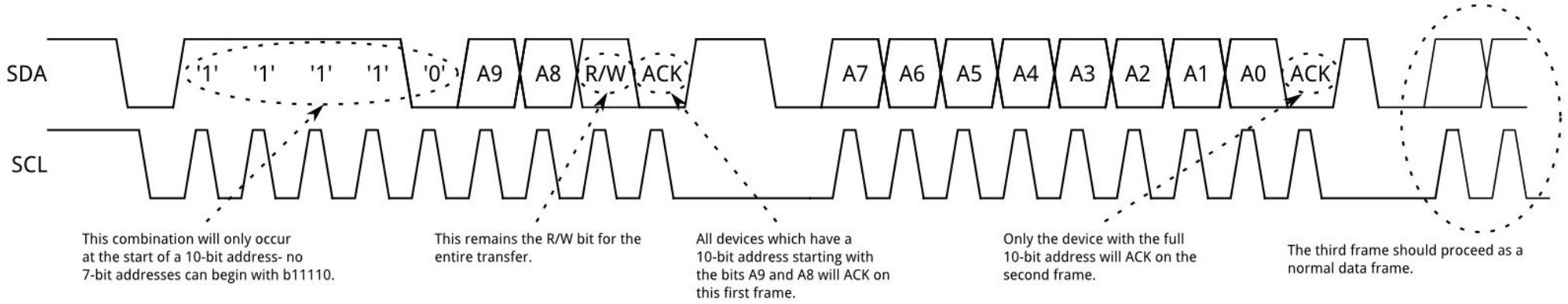


Repeated Start Conditions

It is used when a master wants to exchange several messages without losing the control of the bus.

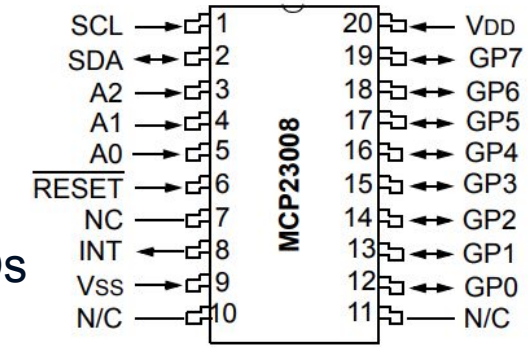
Synchronous Serial Communication (I^2C - Signaling)

- 10-bit Addresses



- Note that 10-bit address devices can coexist with 7-bit address devices
  - The leading '11110' part of the address is not a part of any valid 7-bit addresses

- An I^2C IO expander like MCP23008 can be used to expand the GPIOs



Synchronous Serial Communication (I^2C)

- Some useful links
  - I2C Bus, Interface and Protocol
  - Sparkfun I2C Tutorial
  - How I2C Communication Works?
  - Basics of the I2C Communication Protocol
  - What is I2C, Basics for Beginners
  - I2C Protocol Tutorial | How I2C Protocol works