Basics of I2C:
The I2C Protocol

TIPL 6101
TI Precision Labs – Digital Communications

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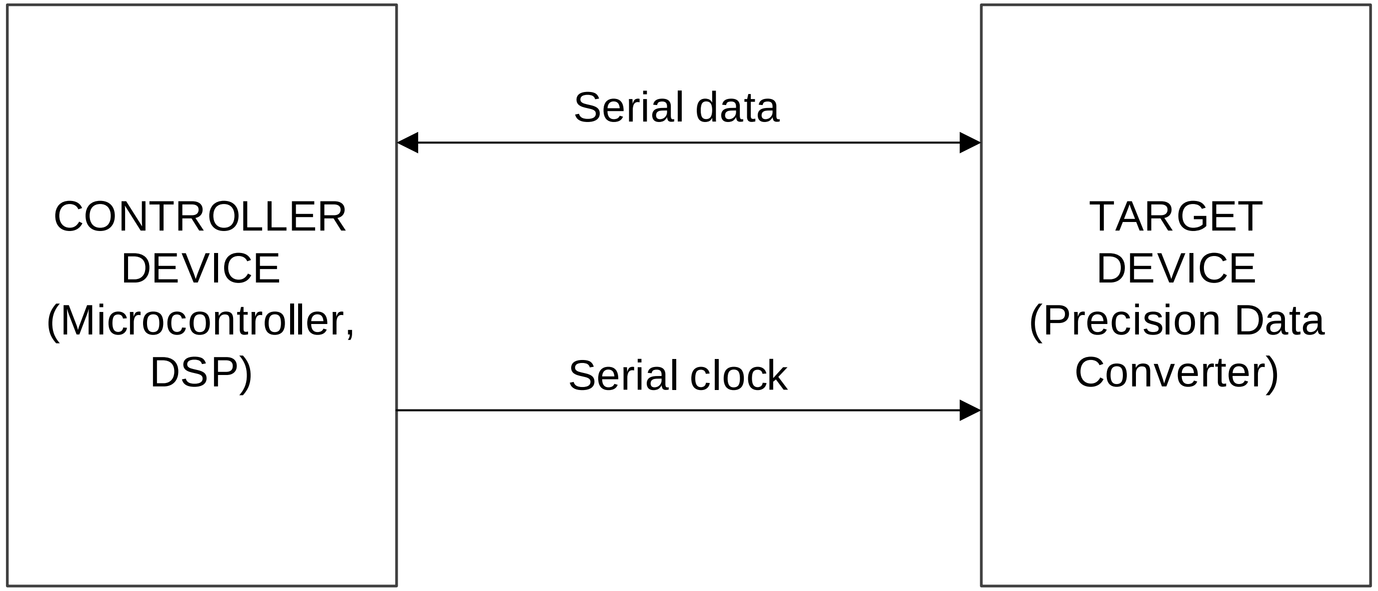
Presented by Alex Smith

I2C Introduction



I2C Introduction
I2C – Inter Integrated Circuit
Created by Philips Semiconductor in 1982
No license needed since 2006, many I2C compatible device manufacturers
Widely used protocol

I2C Communication Modes

I2C Mode	Speed
Standard Mode	100 kbps
Fast Mode	400 kbps
Fast Mode Plus	1 Mbps
High Speed Mode	3.4 Mbps
Ultra-Fast Mode	5 Mbps

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Similar in implementation, with different timing requirements

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Requires controller code for high speed transfer

I2C Communication Modes

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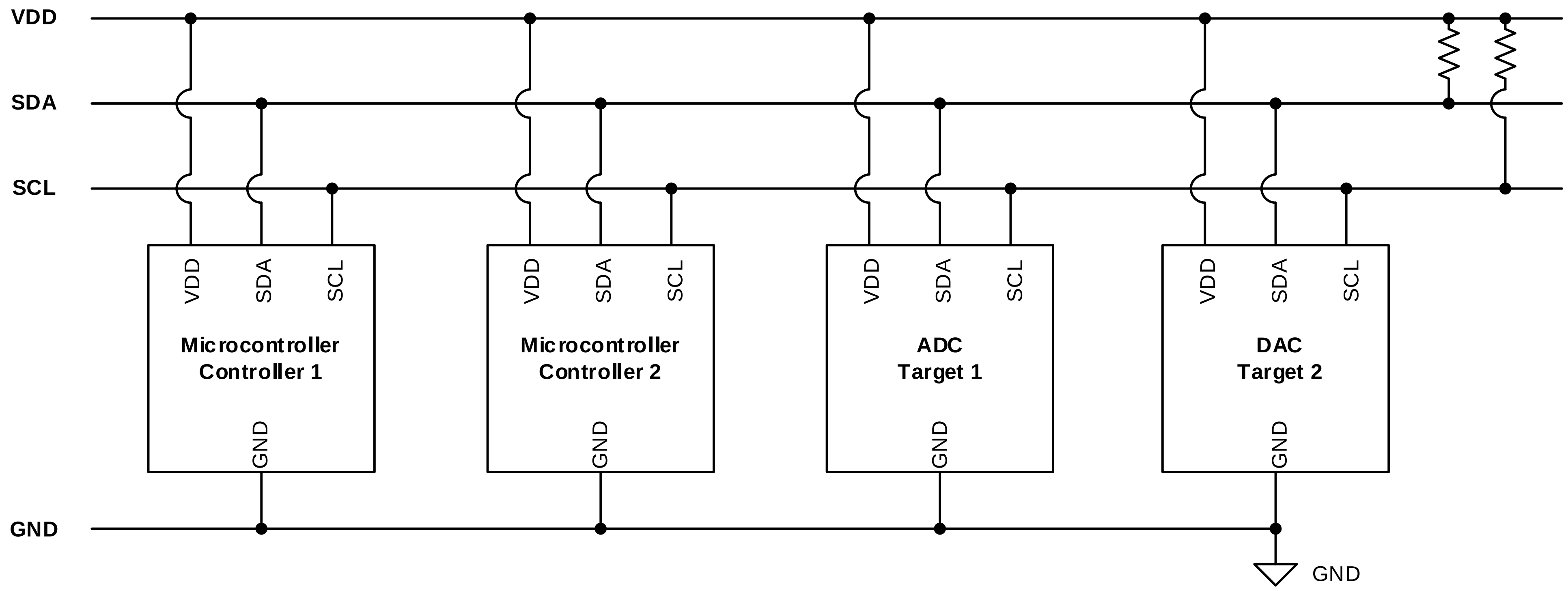
Write-only, omits some standard I2C features

I2C Physical Layer



I2C System Features

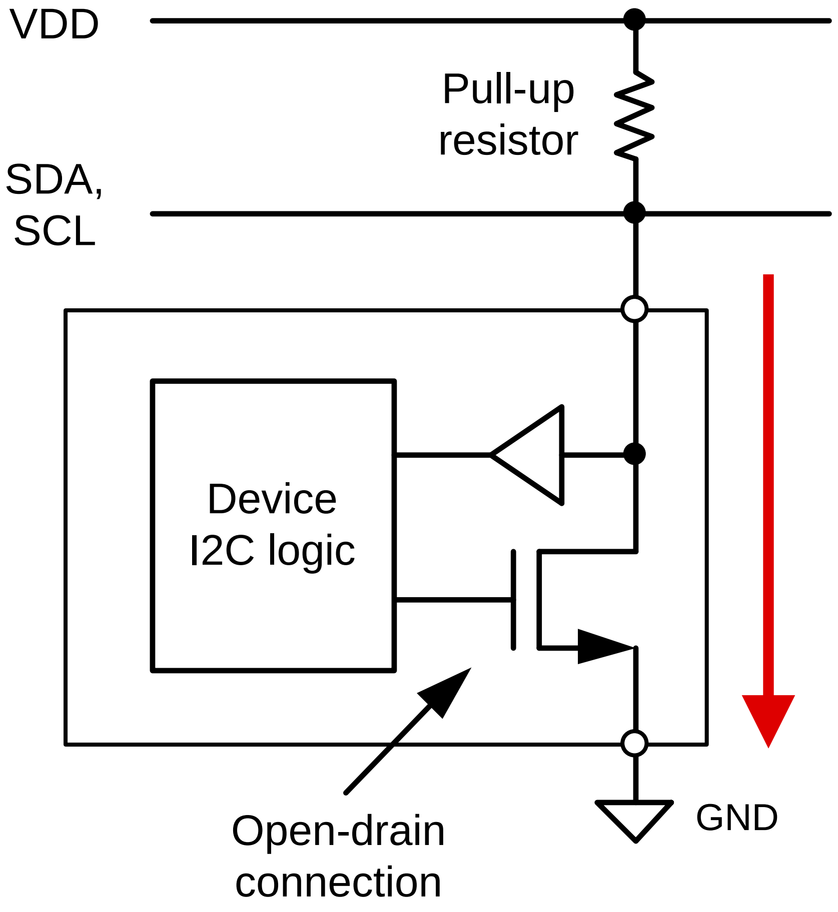
Only two communication lines for all devices on the bus (SDA, SCL)

Bi-directional communication, half duplex

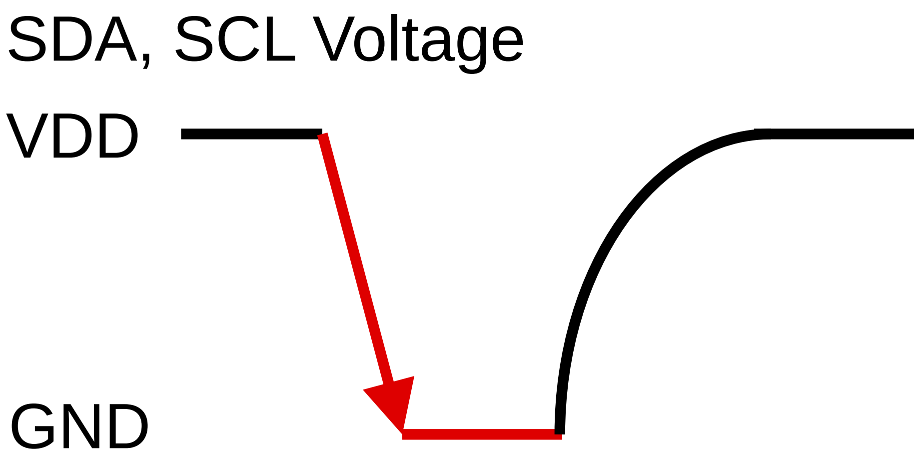
Allows for multiple controllers and multiple targets

Requires pull-up resistors on both SDA and SCL

I2C Physical Layer – Open-Drain Connection

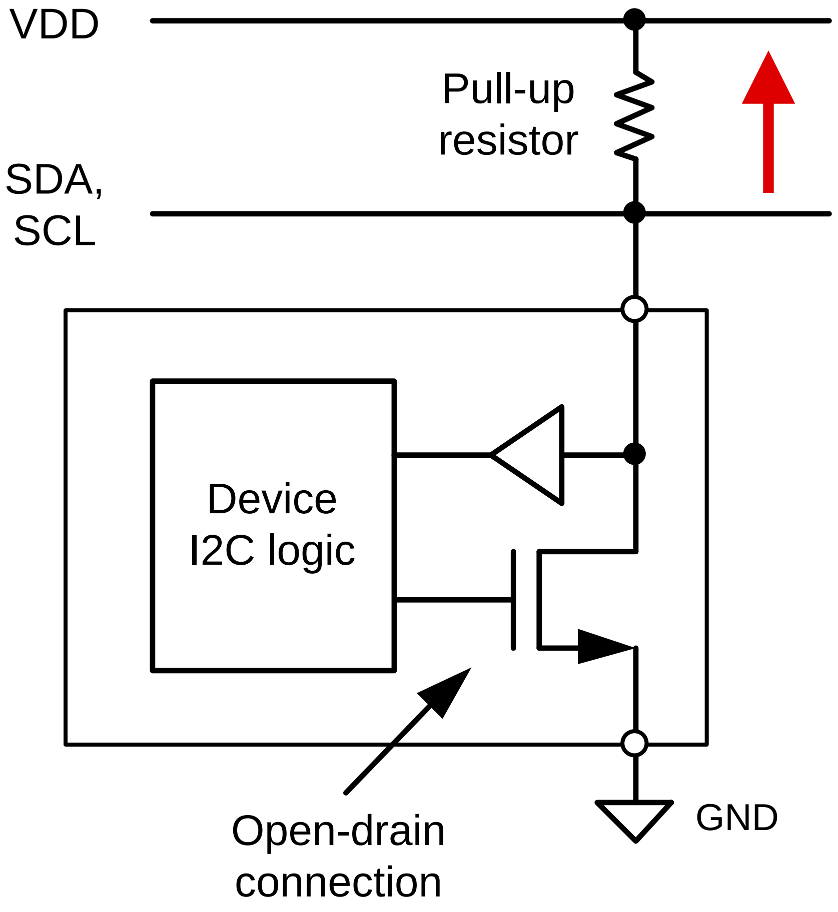


When NMOS turns ON,
SDA or SCL is pulled low

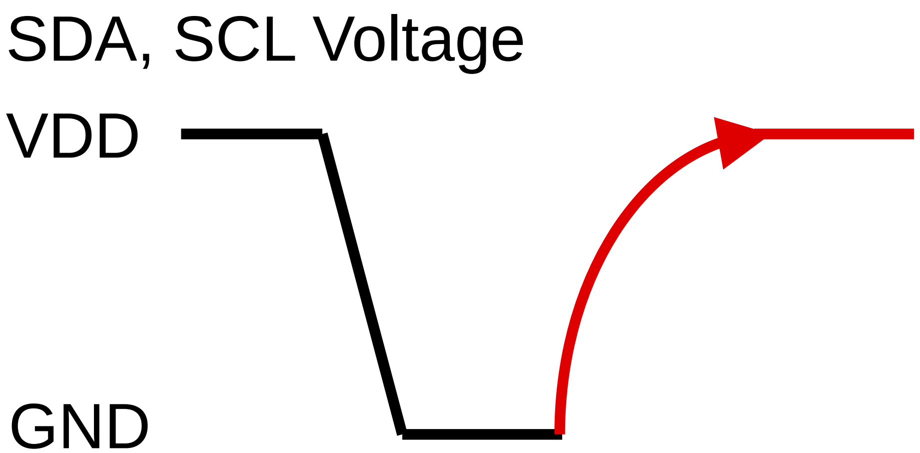


Quick transition from high to low as NMOS pulls charge from any bus capacitance from SDA, SCL

I2C Physical Layer – Open-Drain Connection



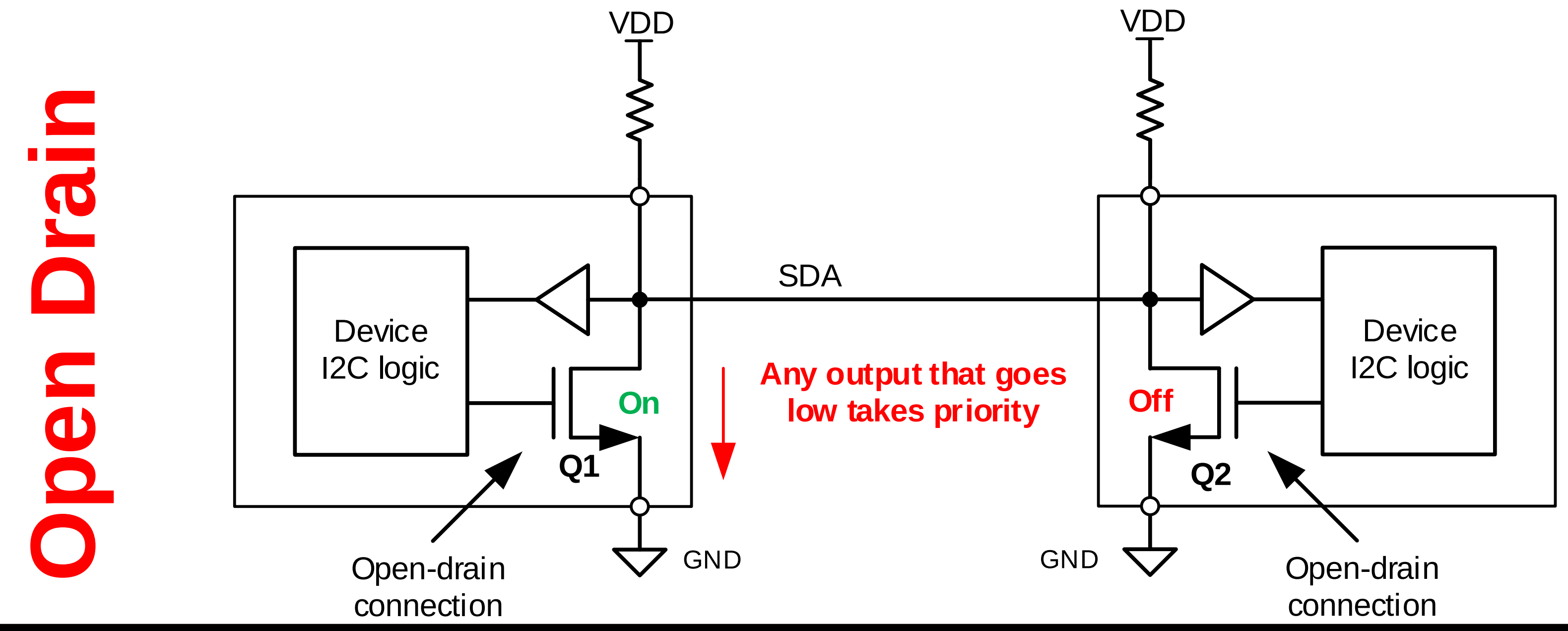
When NMOS turns OFF,
SDA or SCL is released and returns high from the pullup resistor



Exponential rise depends on capacitance on SDA or SCL and pullup resistor size

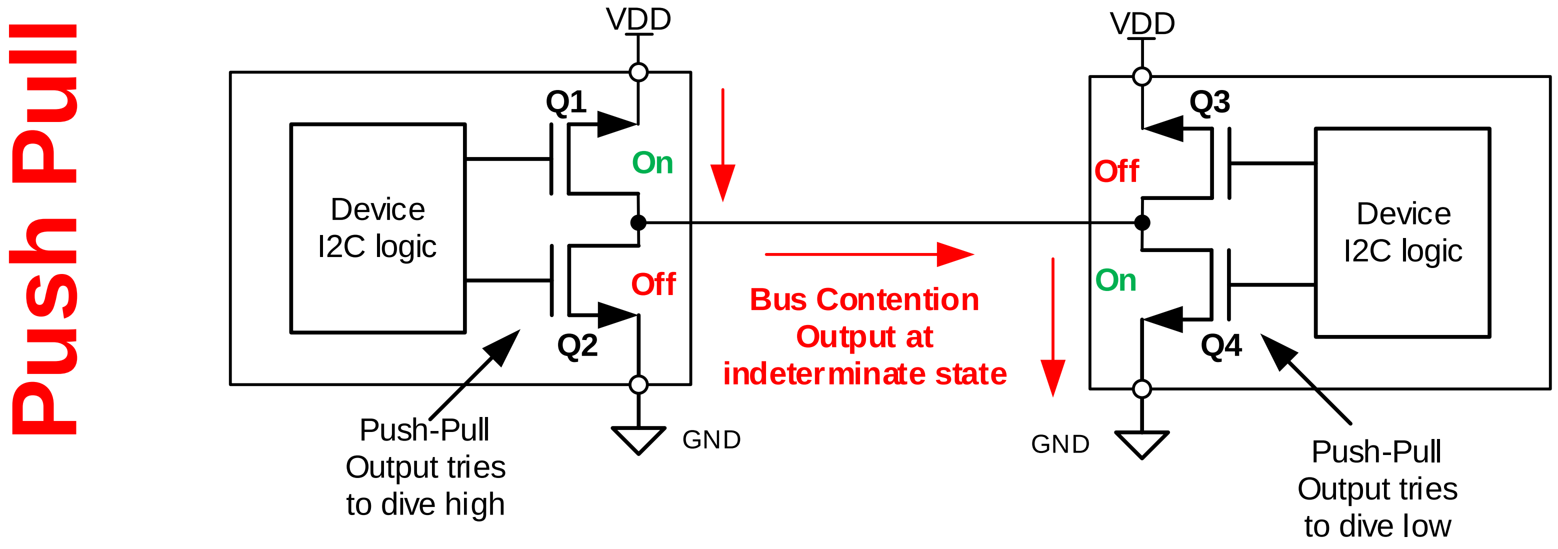
Low resistance: faster communication, more power
High resistance: slower communication, less power

I2C Physical Layer – Open Collector vs Push-Pull



Open Drain

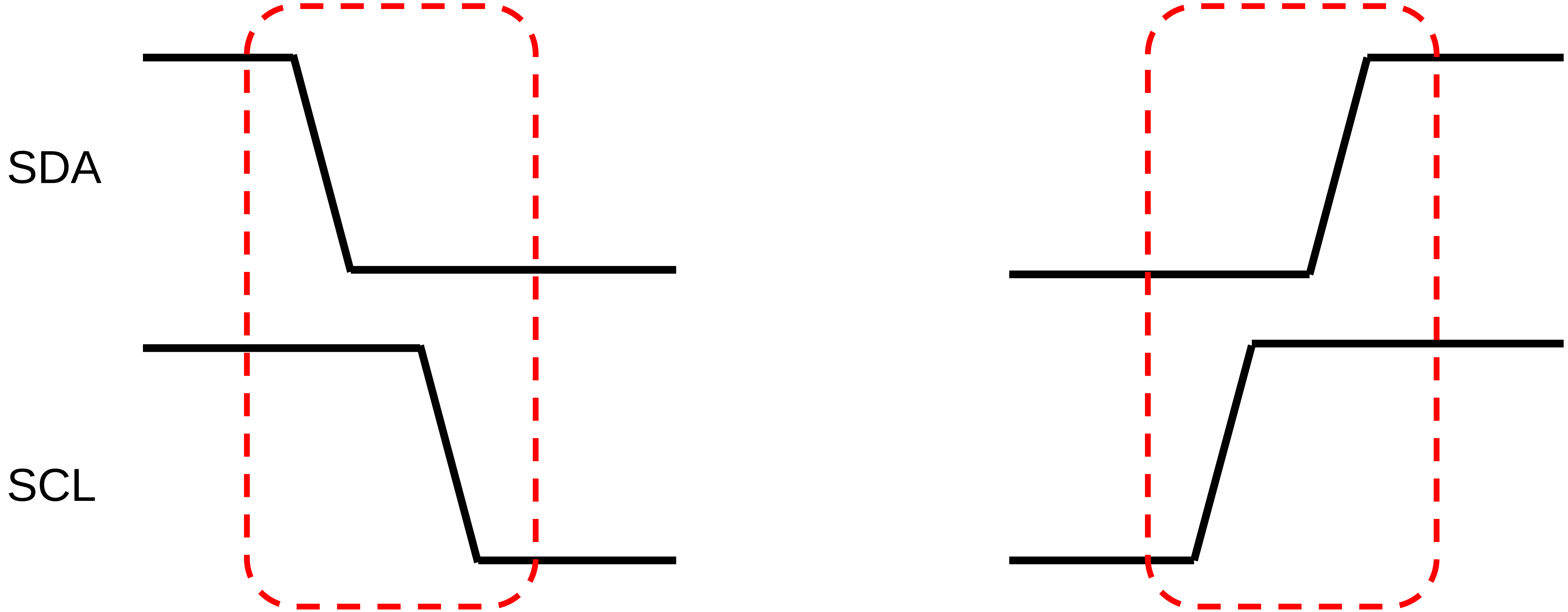
- Open drain output can connect together
- Any output that goes low will pull the bus low
- This type of connection is called a “wired-OR”



Push-Pull

- Open drain output cannot connect together
- Connecting outputs together can cause a bus contention where the output state is indeterminate

I2C Protocol – START and STOP



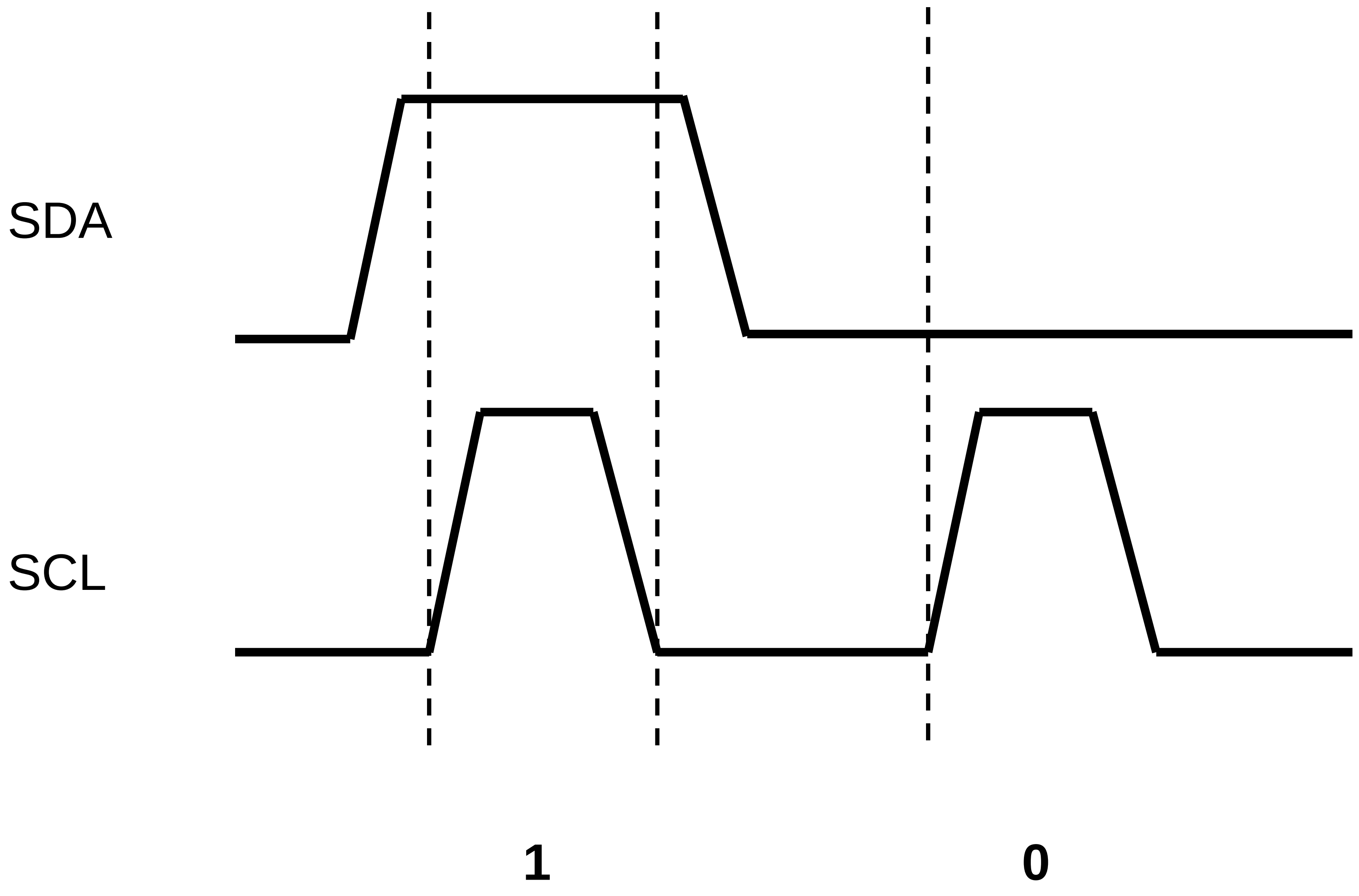
I2C START

A controller device claims the I2C bus for communication with a target device

I2C STOP

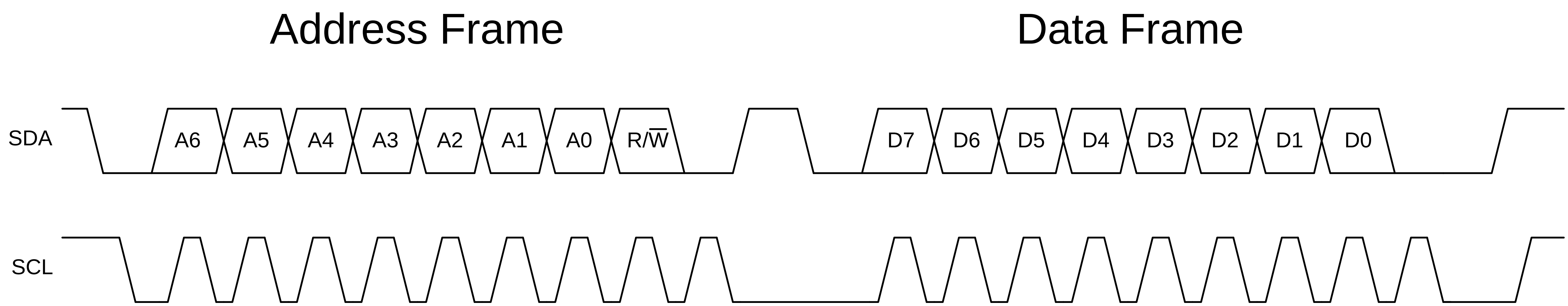
A controller device completes communication with a target device and releases the I2C bus

I2C Protocol – Logical Ones and Zeros

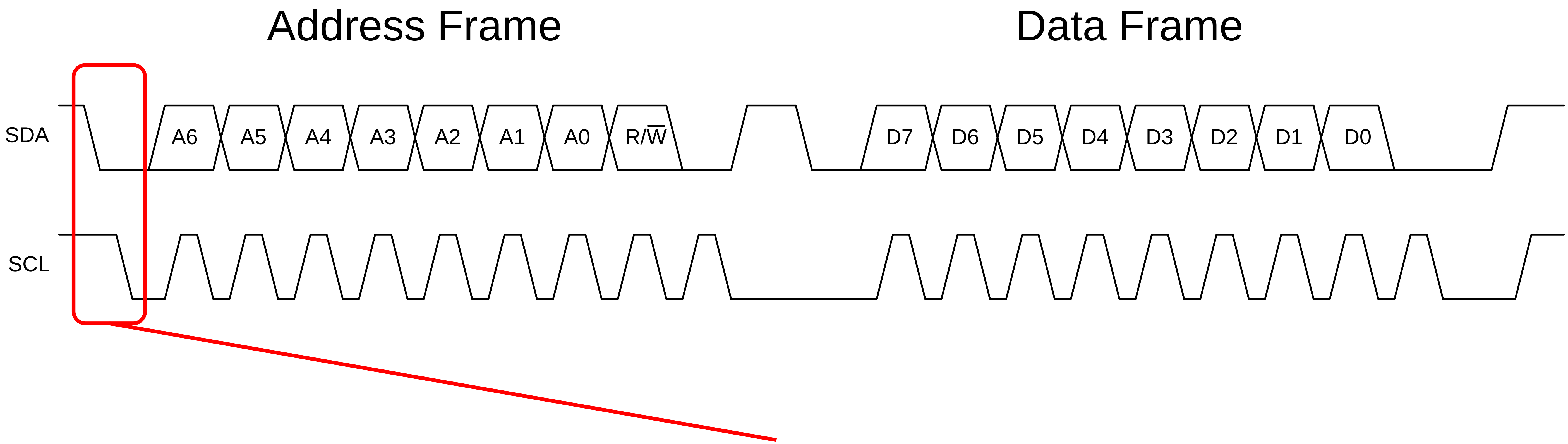


I2C Logical Bits
SDA is the data line, SCL is serial clock
SDA only transitions when SCL is low (except during START and STOP)
SDA is high when SCL pulses is a logical one
SDA is low when SCLK pulses is a logical zero

I2C Protocol – Timing Diagram

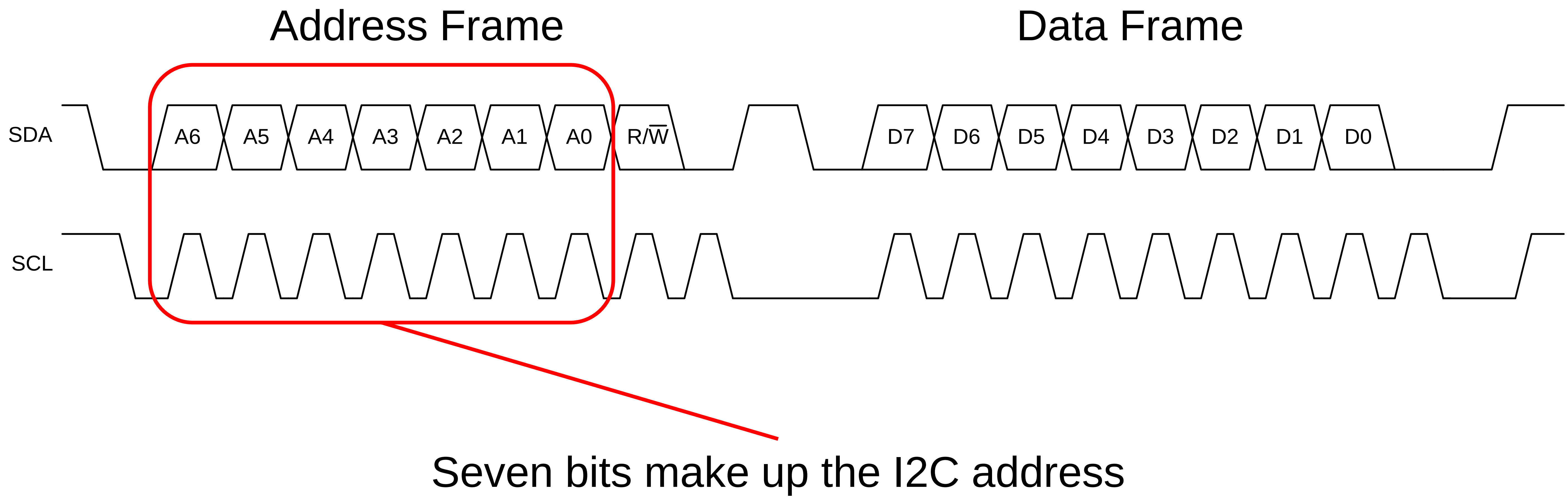


I2C Protocol – Timing Diagram

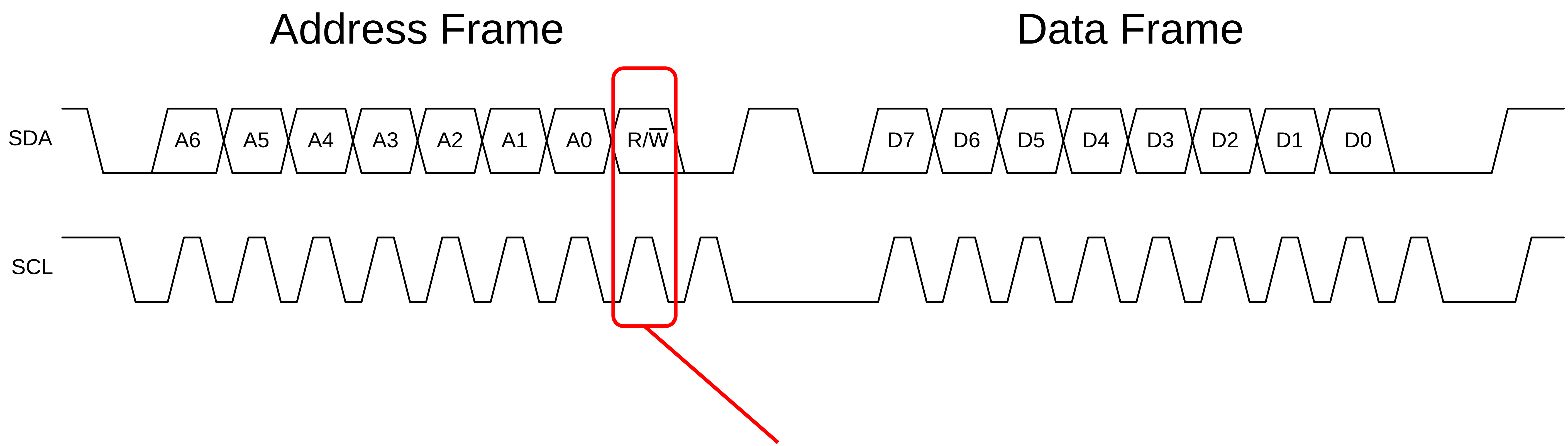


An I2C START condition comes from the controller and sends SDA low before SCL is sent low to claim the bus

I2C Protocol – Timing Diagram

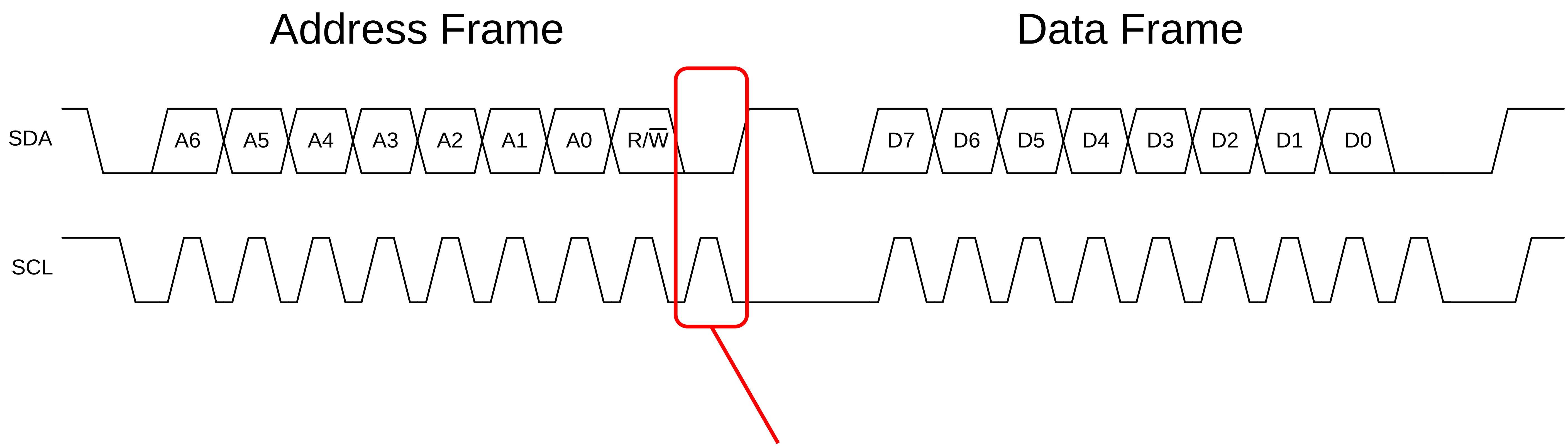


I2C Protocol – Timing Diagram



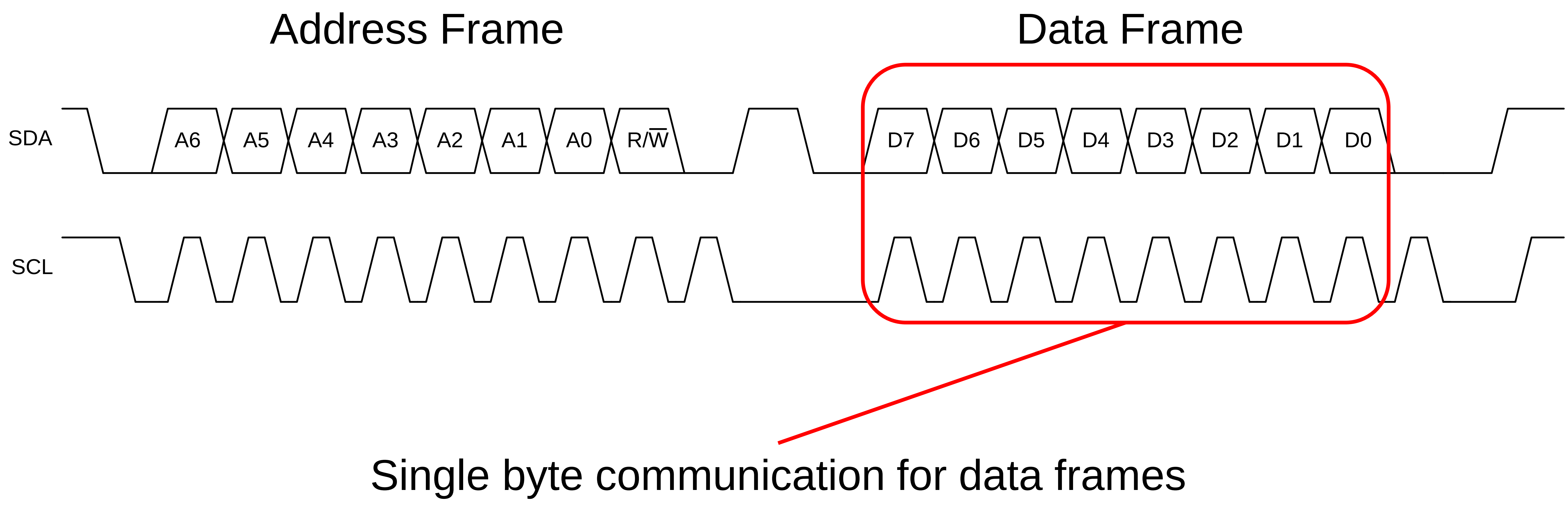
R/W bit indicates the direction of communication
1: Controller wants to read from the target device
0: Controller wants to write to the target device

I2C Protocol – Timing Diagram

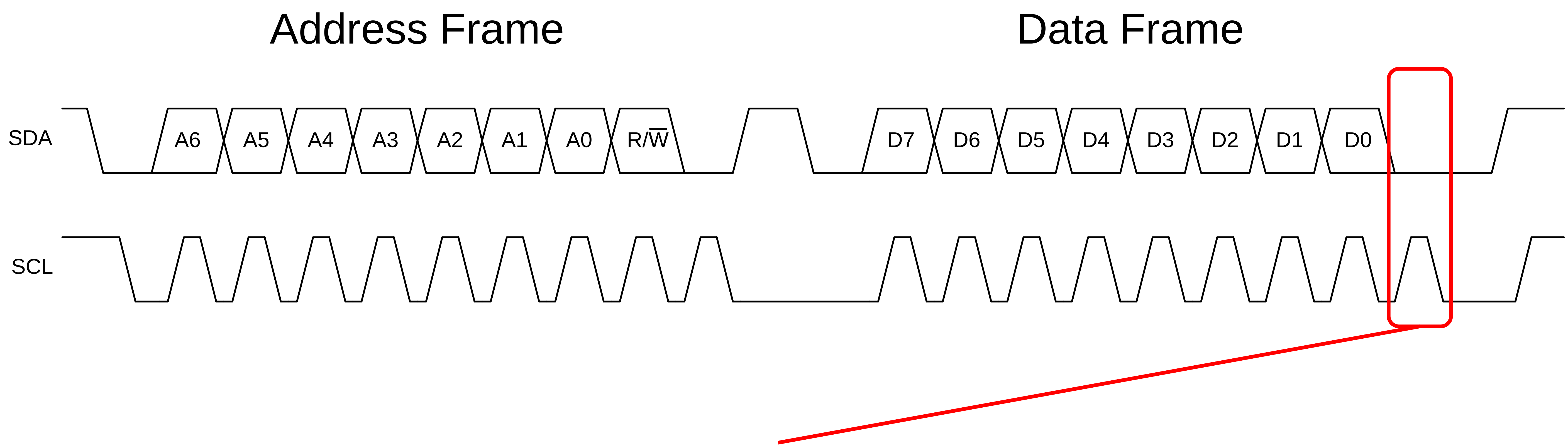


SDA is pulled down as an ACKT (acknowledge, target)
After the address byte, the target device ACKs the communication

I2C Protocol – Timing Diagram

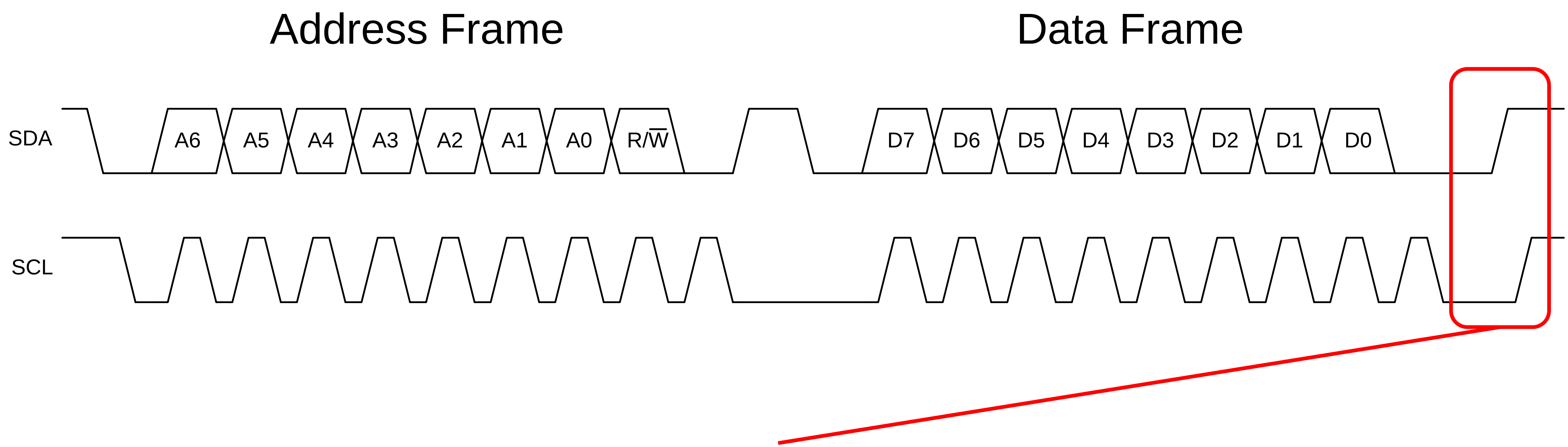


I2C Protocol – Timing Diagram



ACK follows each data frame
Write to the target – ACKT comes from the target device
Read from the target – ACKC comes from the controller device

I2C Protocol – Timing Diagram



I2C STOP condition comes from the controller and sends SDA high before SCL is sent high to release the bus

Thanks for your time! Please try the quiz.

Quiz: Basics of I2C: The I2C Protocol

1. Before the address frame of I2C communication, what actions make up the START condition?
   a. The controller device sets the SDA low, and then sets the SCL low
   b. The controller device sets the SCL low, and then sets the SDA low
   c. The controller device sets the SCL low, and the target device pulls the SDA low as an ACK

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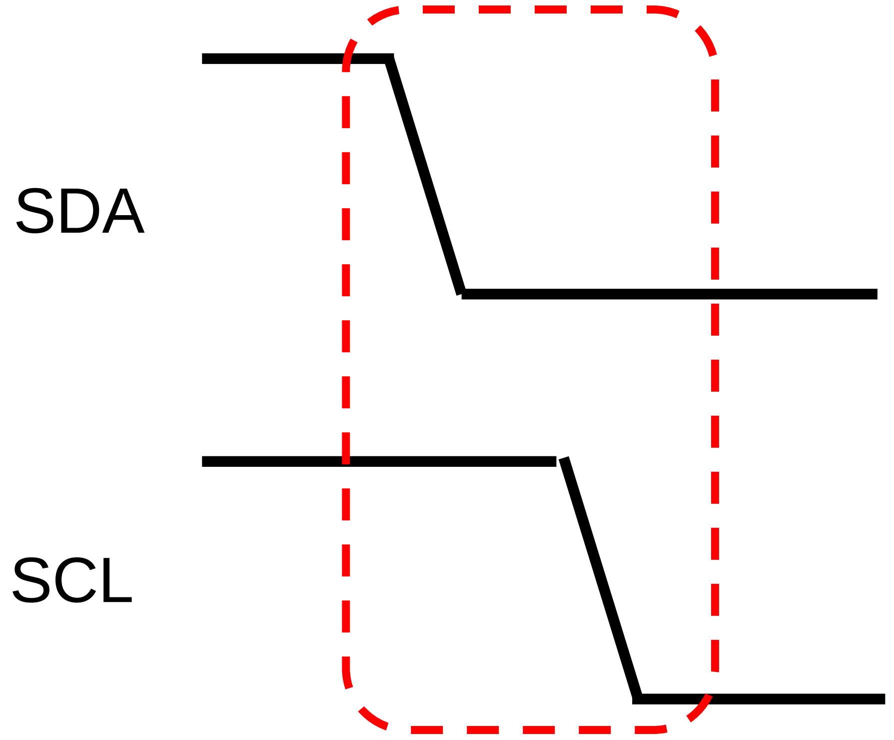

Quiz: Basics of I2C: The I2C Protocol

2. In the address frame, after the controller device sends the 7 bit address, what is the next part of the I2C protocol sent?
   a. The target device sends the ACK to acknowledge the communication coming from the controller device
   b. The controller device sends the R/W bit to indicate if it wants to read from or write to the target device
   c. The controller device send a STOP condition before sending the next data

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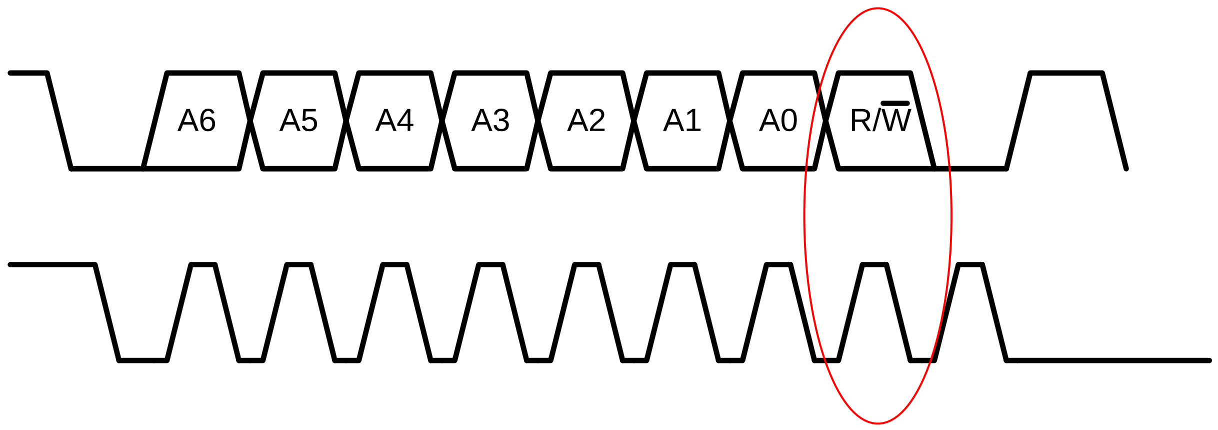

Quiz: Basics of I2C: The I2C Protocol

3. Because of the NMOS open-drain connection to SDA and SCL, which part of the communication waveform is faster?
    a. The rise time of SDA and SCL
    b. The fall time of SDA and SCL
    c. The rise time and fall time of SDA and SCL are the same

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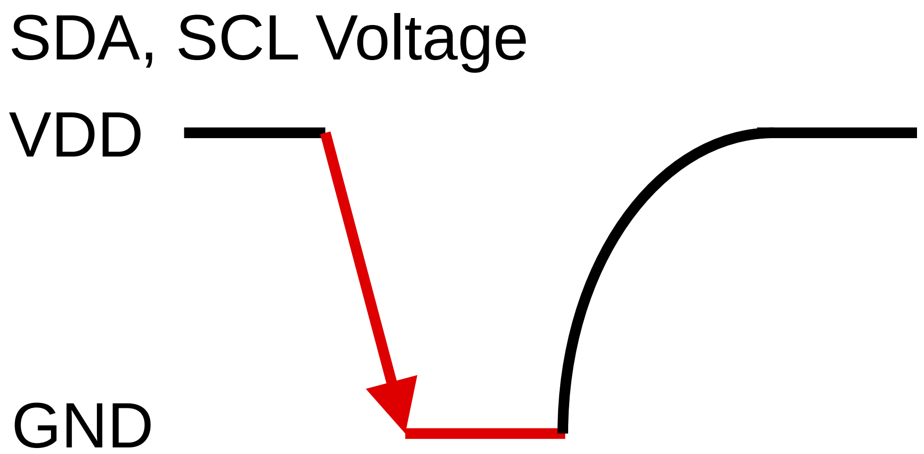

Open-drain connections are actively pulled down instead and are faster than a resistive pull up

Quiz: Basics of I2C: The I2C Protocol

4. What is the benefit of having an open-drain connection over push-pull outputs for I2C?
   a. High speed drive for the bus outputs
   b. Reduction of bus capacitance
   c. Prevents destructive current draw during bus contention when outputs are tied together

Quiz: Basics of I2C: The I2C Protocol

4. What is the benefit of having an open-drain connection over push-pull outputs for I2C?
   a. High speed drive for the bus outputs
   b. Reduction of bus capacitance
   c. Prevents destructive current draw during bus contention when outputs are tied together

Push-Pull outputs may pull a large current when the outputs are tied together and there is bus contention

Thanks for your time!