

## LECTURE VI

# Communication Protocols II

This work by the Institute of Electrical and Electronics Engineers, UC Irvine Branch, is licensed under CC BY-NC-SA 4.0

# A Note on Terminology

---

The words **master** and **slave** pervade modern software and electronics documentation. The terms are inappropriate given their connection to American chattel slavery. Therefore, we are transitioning to new terminology.

There will be a discrepancy between what is discussed in lecture/lab and what is written in our datasheets, but neither the lecture slides nor the OPS team will use the antiquated terminology.

# A Note on Terminology (Cont'd)

---

Use this table for a conversion in terminology wherever you find it in the documentation for our Arduino board and other parts...

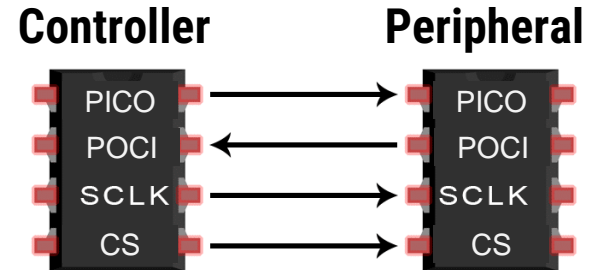
Old Term	New Term
Master	Controller
Slave	Peripheral
MISO	POCI
MOSI	PICO
SS	CS

## SECTION I

**SPI**

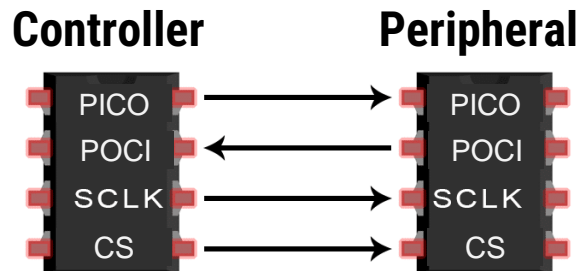
# SPI Protocol

- **Serial Peripheral Interface** or **SPI** is a serial communication protocol which is **synchronized with a clock**
- Unlike UART, **data is transferred continuously** in SPI
  - There are no packets, start bits, stop bits, parity bits, or anything else
- One device acts as a **controller** to one or more **peripheral** devices
- Supports **full-duplex** communication

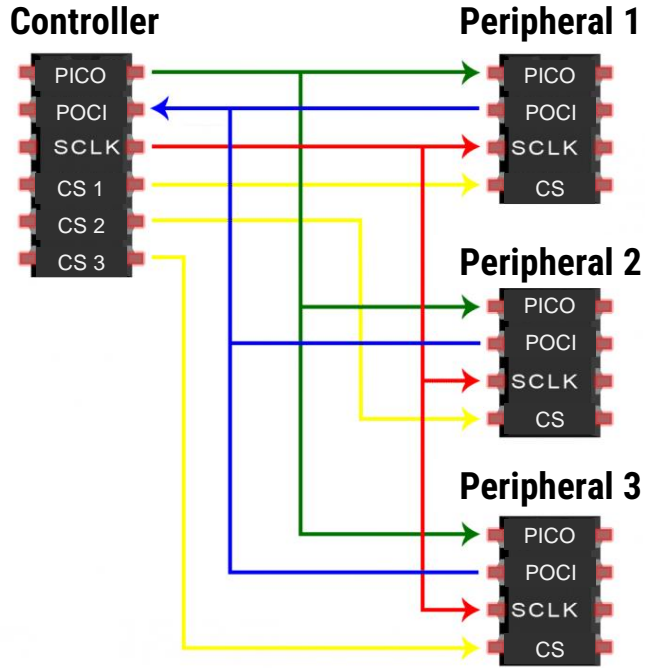


# SPI Layout

- **PICO** (**P**eripheral-**I**n/**C**ontroller-**O**ut) - line for the controller to send data to the peripheral
- **POCI** (**P**eripheral-**O**ut/**C**ontroller-**I**n) - line for the peripheral to send data to the controller
- **SCLK** (**C**lock) - line for the clock signal
- **CS** (**C**hip **S**elect) - line for the controller to select which peripheral to send data

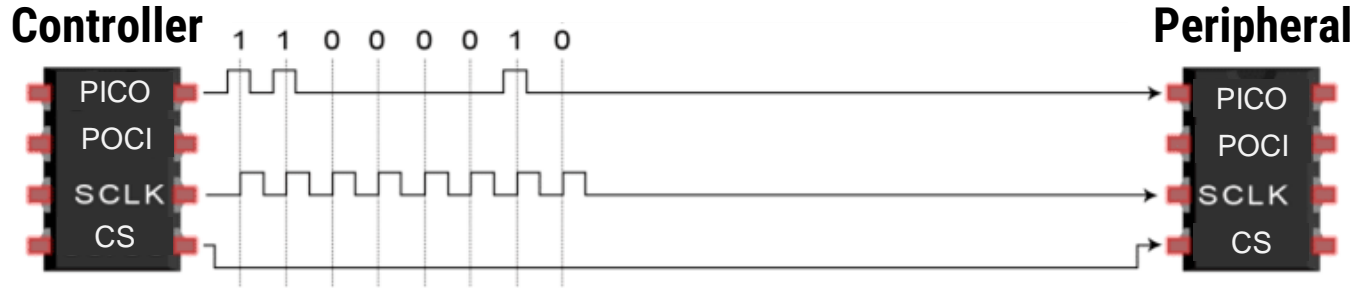


# SPI Layout (Cont'd)



- There is **one controller**
  - Often a microcontroller (Arduino)
  - Generates the clock signal
- The controller controls **one or more peripherals**
  - i.e. Radio module, sensor, actuator
  - In the configuration to the left, there is an **additional CS line for each peripheral**

# SPI Transmission



1. The controller first **selects a peripheral** by pulling a HIGH signal to LOW along the CS line
2. The controller **sends data** to the selected peripheral along the PICO line
  - Bits in the PICO signal are **synchronized with the rising edge** of the oscillating clock signal
  - Alternatively, the peripheral sends data along the POCI line



Please submit questions about the lecture content.

Nobody has responded yet.

Hang tight! Responses are coming in.

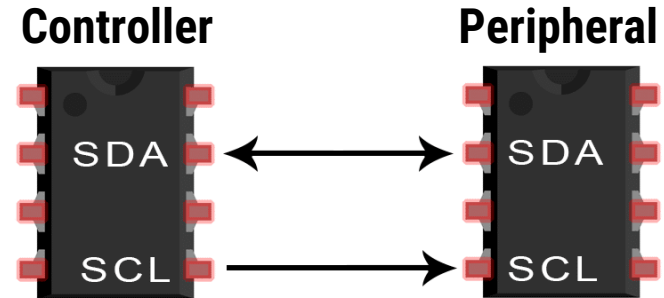


## SECTION II

I<sup>2</sup>C

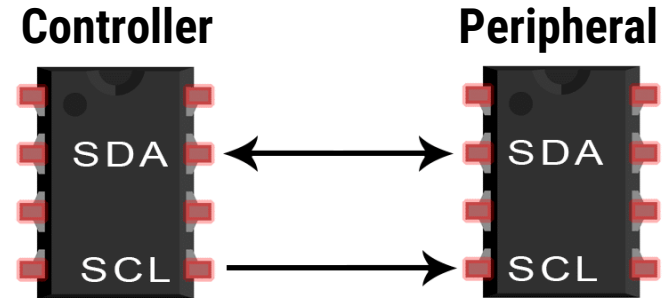
# I<sup>2</sup>C Protocol

- **Inter Integrated Circuit** or **I<sup>2</sup>C** is another synchronized, serial protocol
- Unlike UART and SPI, I<sup>2</sup>C supports **multiple controllers**
- I<sup>2</sup>C features **acknowledgements** to confirm if messages are received and addressing for peripherals
- Supports **half-duplex** communication



# I<sup>2</sup>C Layout

- **SDA (Serial Data)** - the line for the controller and peripheral to send and receive data
- **SCL (Serial Clock)** - the line that carries the clock signal
- All peripherals can share the same two SDA and SCL lines



# I<sup>2</sup>C Frame Format

- Data is transferred as **messages**
- A **start condition** from the controller begins the message
- Each message contains an **address frame** with an address to identify the receiving peripheral

## I<sup>2</sup>C Message



# I<sup>2</sup>C Frame Format (Cont'd)

- The **read/write bit** indicates whether the controller is sending or requesting data
- Then, the peripheral with the matching address sends an **acknowledgement (ACK)** of the message as a single bit

## I<sup>2</sup>C Message



## I<sup>2</sup>C Frame Format (Cont'd)

- Depending on whether the message is read or write, either the controller or peripheral will send **data frames**
- The device receiving data will send an **ACK** before the transmission of the next data frame

## I<sup>2</sup>C Message



# I<sup>2</sup>C Frame Format (Cont'd)

- The devices may transfer as many data frames in one message as desired
- If the controller is reading from the peripheral, it will send a **NACK** to end data transmission
- The controller terminates communication by signalling the **stop condition**
  - Another controller may send a message upon seeing the stop signal

## I<sup>2</sup>C Message





Please submit questions about the lecture content.

Nobody has responded yet.

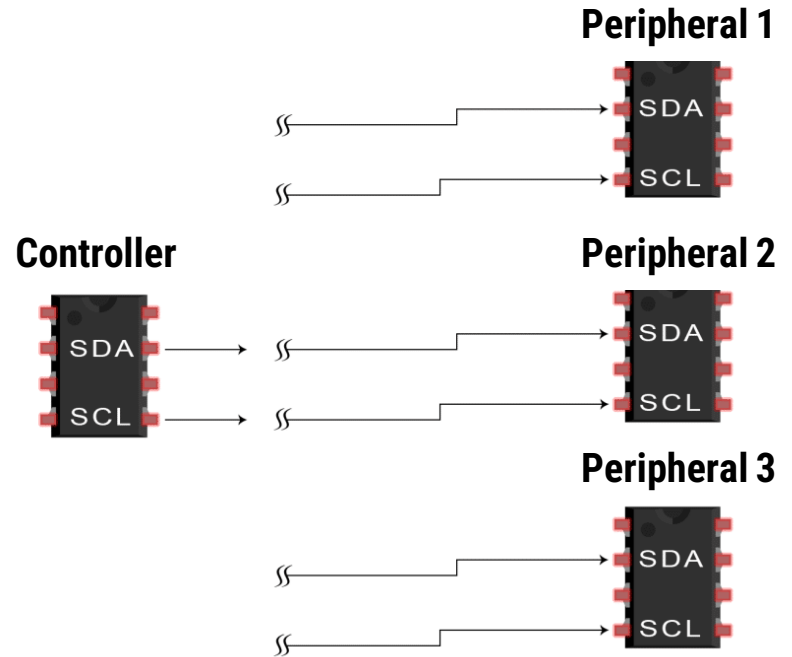
Hang tight! Responses are coming in.



# I<sup>2</sup>C Transmission (Cont'd)

1. The controller outputs the **start condition** to all connected peripherals

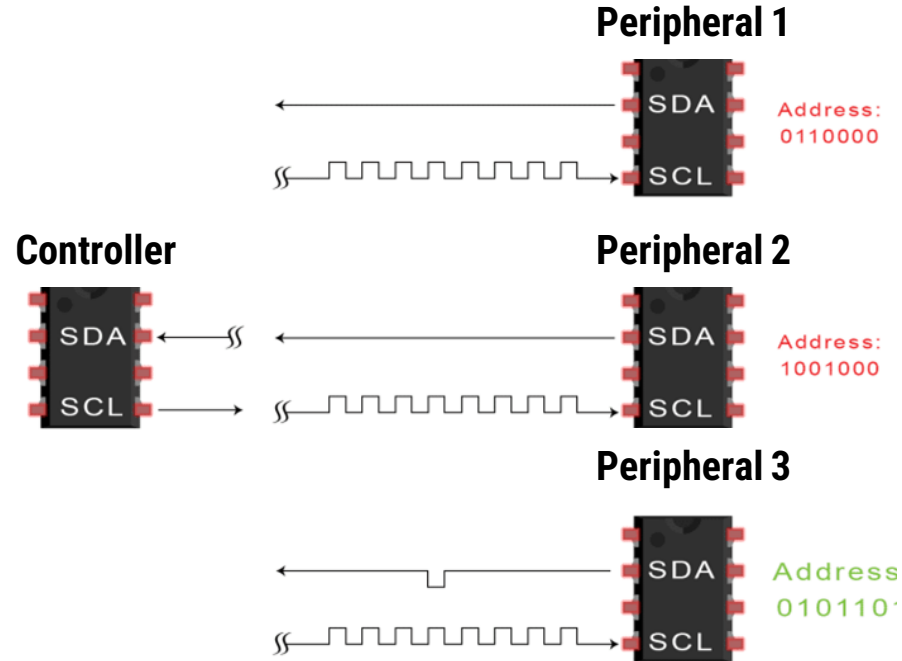
Starting from a **HIGH** voltage in idle, the controller pulls to the voltage down **LOW** on the SDA line *then* the SCL line



# I<sup>2</sup>C Transmission (Cont'd)

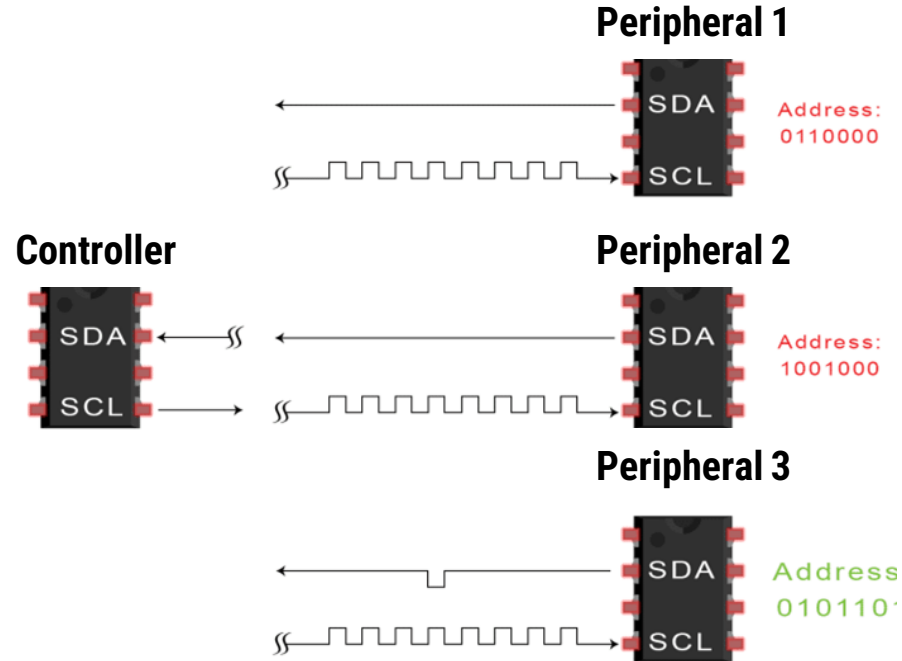
2. The controller then **sends the address** of the peripheral it would like to communicate with

The **last bit of the address is the read/write bit** that indicates whether the controller is sending or receiving data



# I<sup>2</sup>C Transmission (Cont'd)

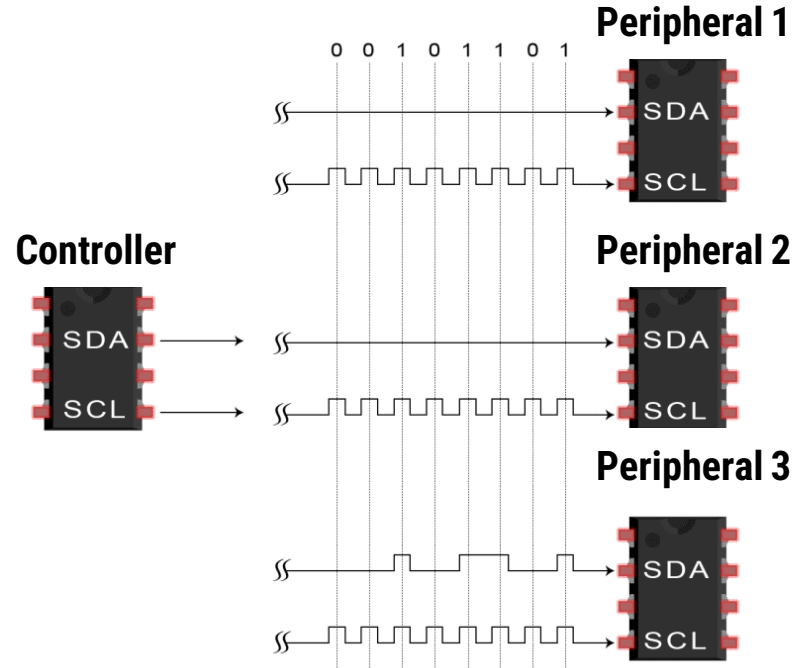
3. The peripheral with the matching address responds with an **ACK**



# I<sup>2</sup>C Transmission (Cont'd)

4. The controller **sends or receives the data frame**, depending on the read/write bit

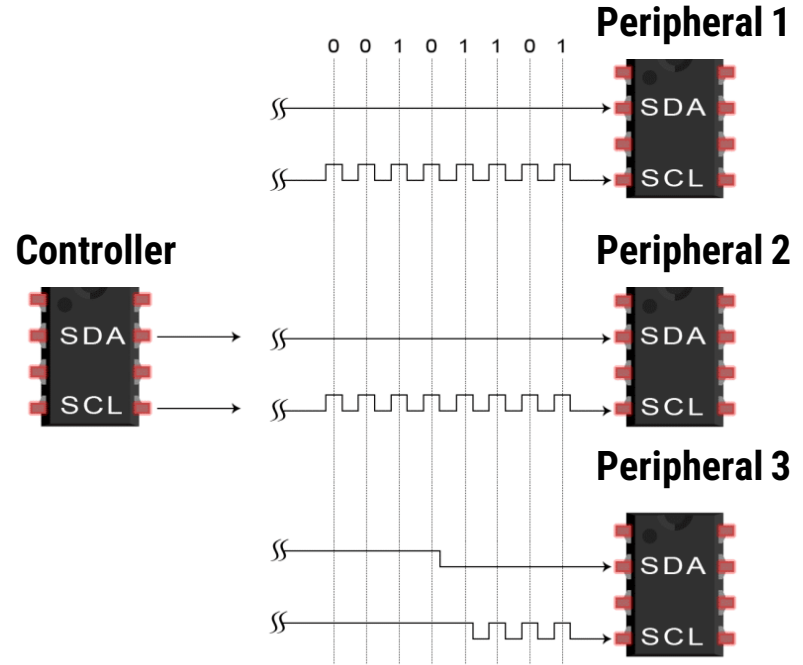
After each transmission, the receiving device sends an ACK for a successful transmission



# I<sup>2</sup>C Transmission (Cont'd)

4. Finally, the controller switches the voltage of the SCL line then the SDA line to **HIGH**, signalling the **stop condition**

The message is complete



Please submit questions about the lecture content.

Nobody has responded yet.

Hang tight! Responses are coming in.






## SECTION III

# Comparing Protocols



# UART vs SPI vs I<sup>2</sup>C

Protocol	UART	SPI	I <sup>2</sup> C
# of Lines	2	4+	2
# of Controllers	1	1	1+
# of Peripherals	1	1+	1+
Transmission Type	Full-Duplex	Full-Duplex	Half-Duplex
Error-Checking			
Speed	Slowest	Fastest	Slower

Please submit questions about the lecture content.

Nobody has responded yet.

Hang tight! Responses are coming in.



# Comparing Protocols

I/A

Visit the Kahoot [here](#)

Which one of the following is a full-duplex communication protocol?

- A. SPI
- B. I<sup>2</sup>C
- C. Both SPI and I<sup>2</sup>C
- D. Neither SPI or I<sup>2</sup>C

Which of the following protocols doesn't require an additional line to support multiple devices on the same bus?

- A. SPI
- B. I<sup>2</sup>C
- C. Both SPI and I<sup>2</sup>C
- D. Neither SPI or I<sup>2</sup>C

Which of the following protocols supports multiple controllers and peripherals?

- A. SPI
- B. I<sup>2</sup>C
- C. UART
- D. Both UART and I<sup>2</sup>C

# Comparing Protocols

I/A

Which of the following protocols doesn't have start and stop bits?

- A. SPI
- B. I<sup>2</sup>C
- C. UART
- D. Both UART and I<sup>2</sup>C

# Comparing Protocols

The SCLK, PICO, POCI, CS are the four data lines in \_\_\_\_\_ protocol.

- A. SPI
- B. I<sup>2</sup>C
- C. UART
- D. Both SPI and I<sup>2</sup>C



Which of the following communication protocols is a type of synchronous protocol?

- A. SPI
- B. I<sup>2</sup>C
- C. UART
- D. Both SPI and I<sup>2</sup>C

Which one of the following protocols needs a clock?

- A. SPI
- B. I<sup>2</sup>C
- C. UART
- D. Both SPI and I<sup>2</sup>C

# Comparing Protocols

The receiver and transmitter are the two data lines in \_\_\_\_\_ protocol.

- A. SPI
- B. I<sup>2</sup>C
- C. UART
- D. Both SPI and I<sup>2</sup>C

Which of the following protocols needs a chip select line?

- A. SPI
- B. I<sup>2</sup>C
- C. UART
- D. Both SPI and I<sup>2</sup>C

Which of the following protocols is a single controller, single peripheral communication protocol?

- A. SPI
- B. I<sup>2</sup>C
- C. UART
- D. Both SPI and I<sup>2</sup>C

How many signal lines does I<sup>2</sup>C Protocol require?

- A. 1
- B. 2
- C. 4

How many signal lines does UART Protocol require?

- A. 1
- B. 2
- C. 4

Which of the following protocols is best for multiple peripherals over the fewest lines?

- A. SPI
- B. I<sup>2</sup>C
- C. UART



Which of the following protocols is best for multiple peripherals with the highest transmission rate?

- A. SPI
- B. I<sup>2</sup>C
- C. UART

Which of the following protocols is best for full-duplex communication with multiple peripherals?

- A. SPI
- B. I<sup>2</sup>C
- C. UART

Which of the following protocols consumes less power?

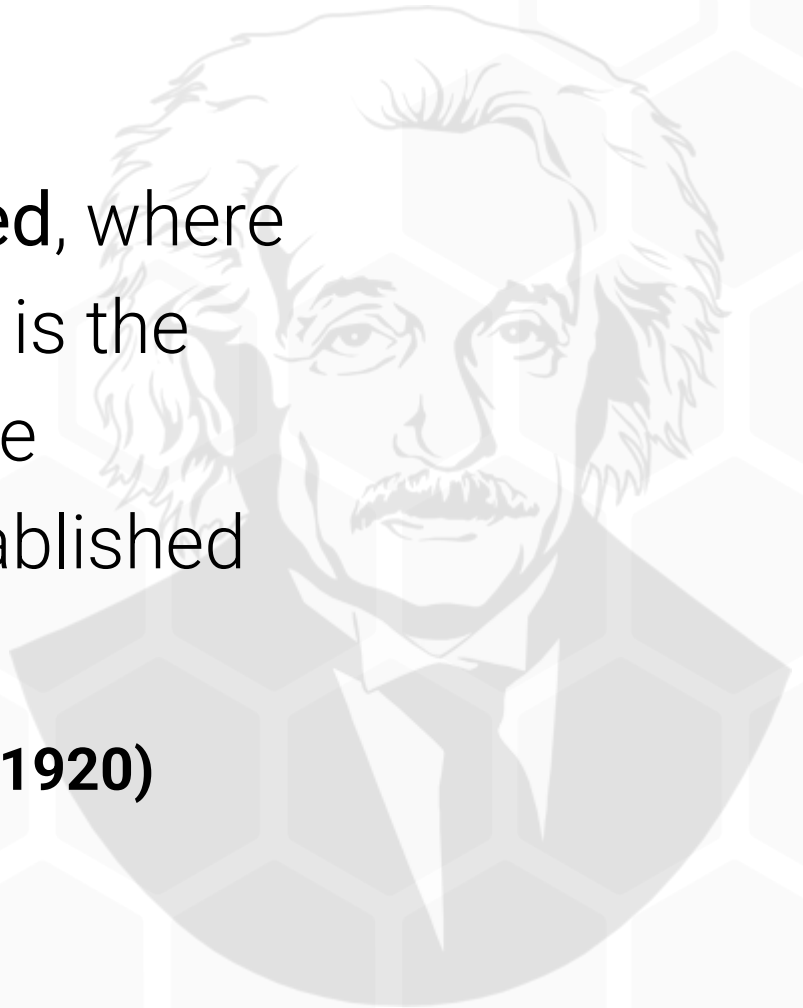
A. SPI

B. I<sup>2</sup>C

“E equals MC serially squared, where M is the mighty data byte, C is the constant bit rate, and E is the enlightenment of a well-established communication protocol.”

**Albert Einstein (circa 1920)**

Famous Misquotes



# FAIR USE DISCLAIMER

Copyright Disclaimer under section 107 of the Copyright Act 1976, allowance is made for “fair use” for purposes such as criticism, comment, news reporting, teaching, scholarship, education and research.

Fair use is a use permitted by copyright statute that might otherwise be infringing.

Non-profit, educational or personal use tips the balance in favor of fair use.

## CC BY-NC-SA 4.0

This work by the Institute of Electrical and Electronics Engineers, UC Irvine Branch, is licensed under CC BY-NC-SA 4.0