M14 – I2C communication protocol

https://www.byteparadigm.com/applications/introduction-to-i2c-and-spi-protocols/

I^{2}C

I^{2}C is a multi-master protocol that uses 2 signal lines. The two I^{2}C signals are called ‘serial data’ (SDA) and ‘serial clock’ (SCL). There is no need of chip select (slave select) or arbitration logic. Virtually any number of slaves and any number of masters can be connected onto these 2 signal lines and communicate between each other using a protocol that defines:

– 7-bits slave addresses: each device connected to the bus has got such a unique address;

– data divided into 8-bit bytes

– a few control bits for controlling the communication start, end, direction and for an acknowledgment mechanism.

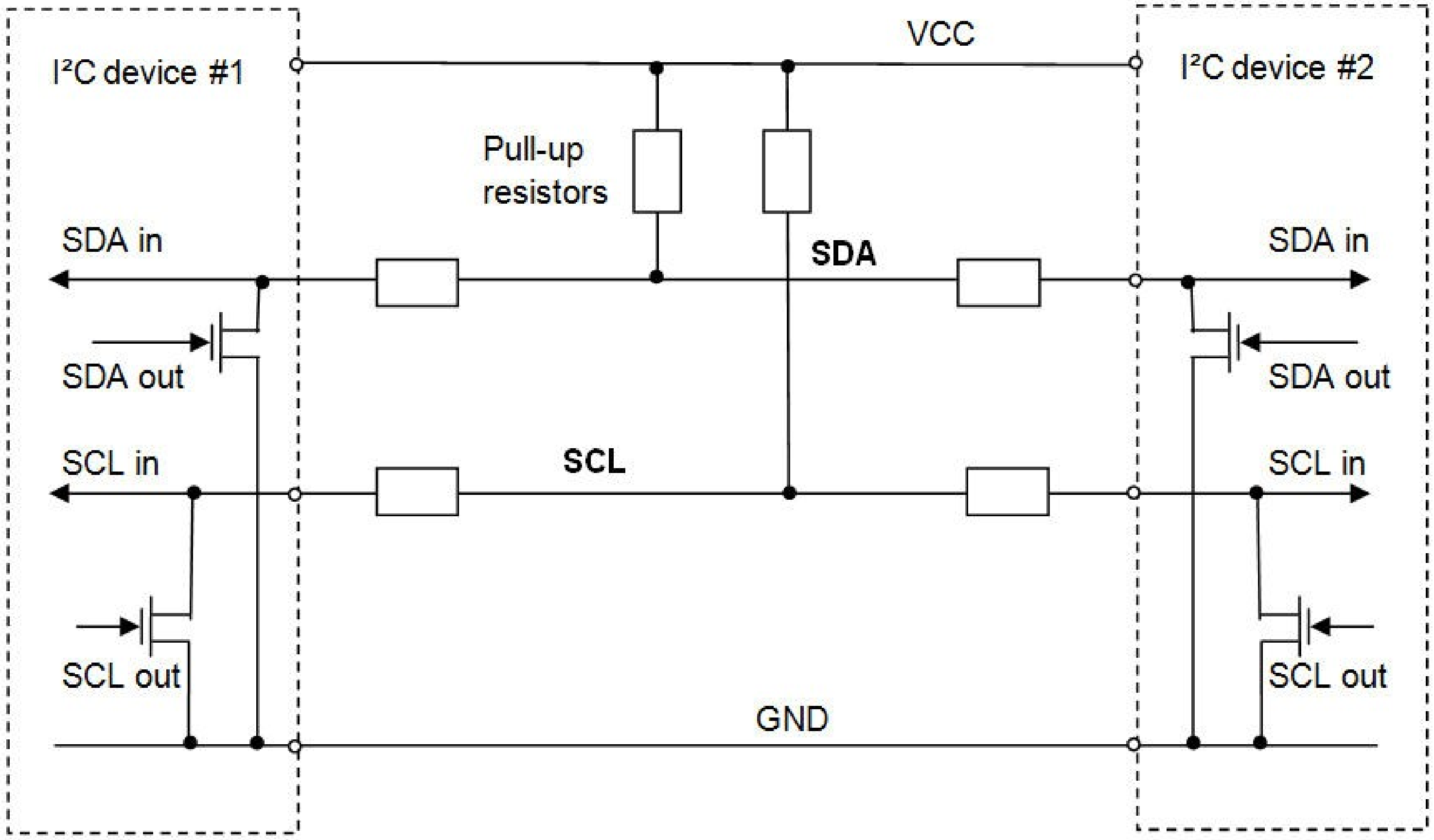
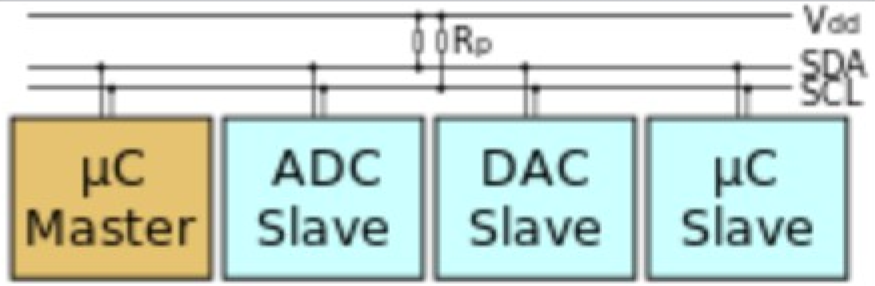


Figure 4: I²C bus with 2 devices connected. SDA and SCL are connected to VCC through pull-up resistors. Each device controls the bus lines outputs with open drain buffers.



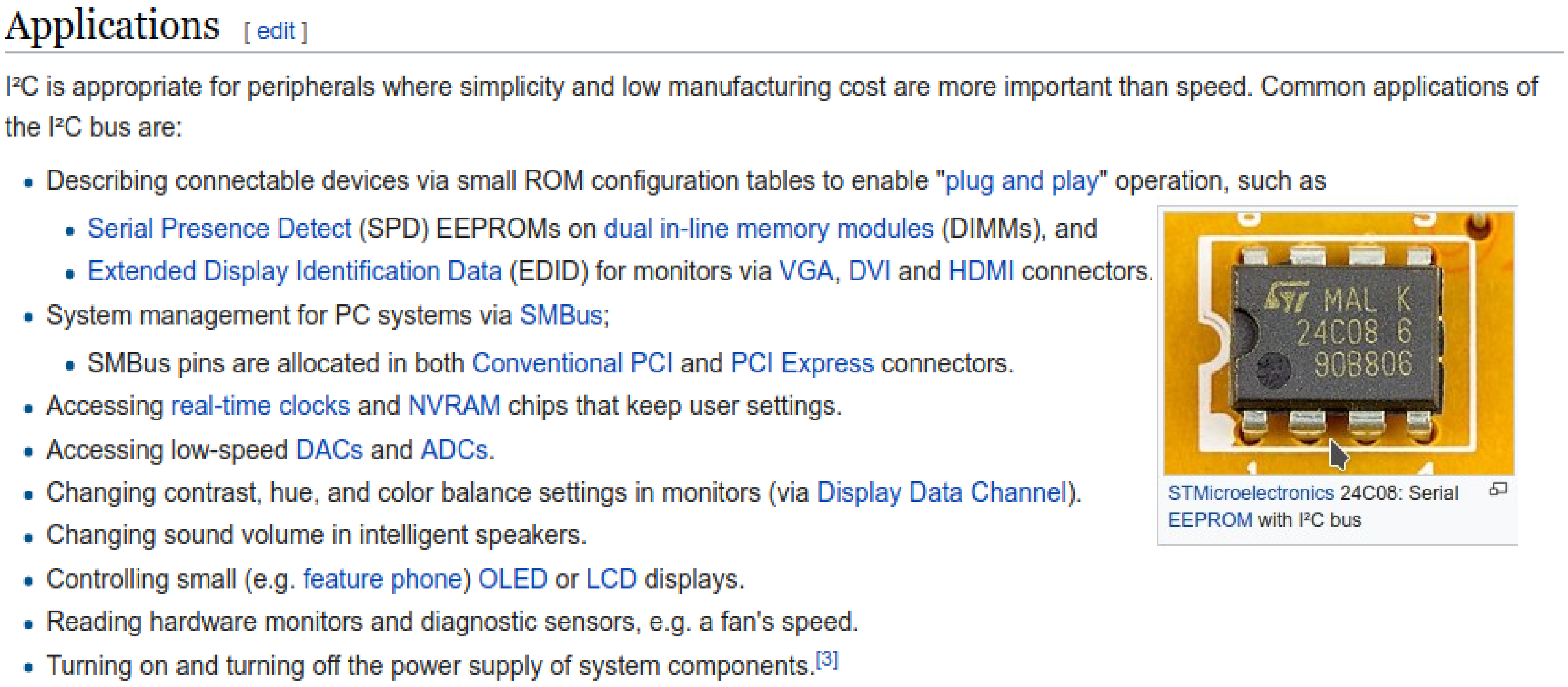
An example schematic with one master (a microcontroller), three slave nodes (an ADC, a DAC, and a microcontroller), and pull-up resistors R_p

The data rate has to be chosen between 100 kbps, 400 kbps and 3.4 Mbps, respectively called standard mode, fast mode and high speed mode. Some I²C variants include 10 kbps (low speed mode) and 1 Mbps (fast mode +) as valid speeds.

Physically, the I²C bus consists of the 2 active wires SDA and SCL and a ground connection (refer to figure 4). The active wires are both bi-directional. The I2C protocol specification states that the IC that initiates a data transfer on the bus is considered the Bus Master. Consequently, at that time, all the other ICs are regarded to be Bus Slaves.

https://en.wikipedia.org/wiki/I²C

A particular strength of I²C is the capability of a microcontroller to control a network of device chips with just two general-purpose I/O pins and software



Applications [edit]

I²C is appropriate for peripherals where simplicity and low manufacturing cost are more important than speed. Common applications of the I²C bus are:

- Describing connectable devices via small ROM configuration tables to enable "plug and play" operation, such as
  - Serial Presence Detect (SPD) EEPROMs on dual in-line memory modules (DIMMs), and
  - Extended Display Identification Data (EDID) for monitors via VGA, DVI and HDMI connectors.
- System management for PC systems via SMBus;
  - SMBus pins are allocated in both Conventional PCI and PCI Express connectors.
- Accessing real-time clocks and NVRAM chips that keep user settings.
- Accessing low-speed DACs and ADCs.
- Changing contrast, hue, and color balance settings in monitors (via Display Data Channel).
- Changing sound volume in intelligent speakers.
- Controlling small (e.g. feature phone) OLED or LCD displays.
- Reading hardware monitors and diagnostic sensors, e.g. a fan's speed.
- Turning on and turning off the power supply of system components.[3]

STMicroelectronics 24C08: Serial EEPROM with I²C bus

Details

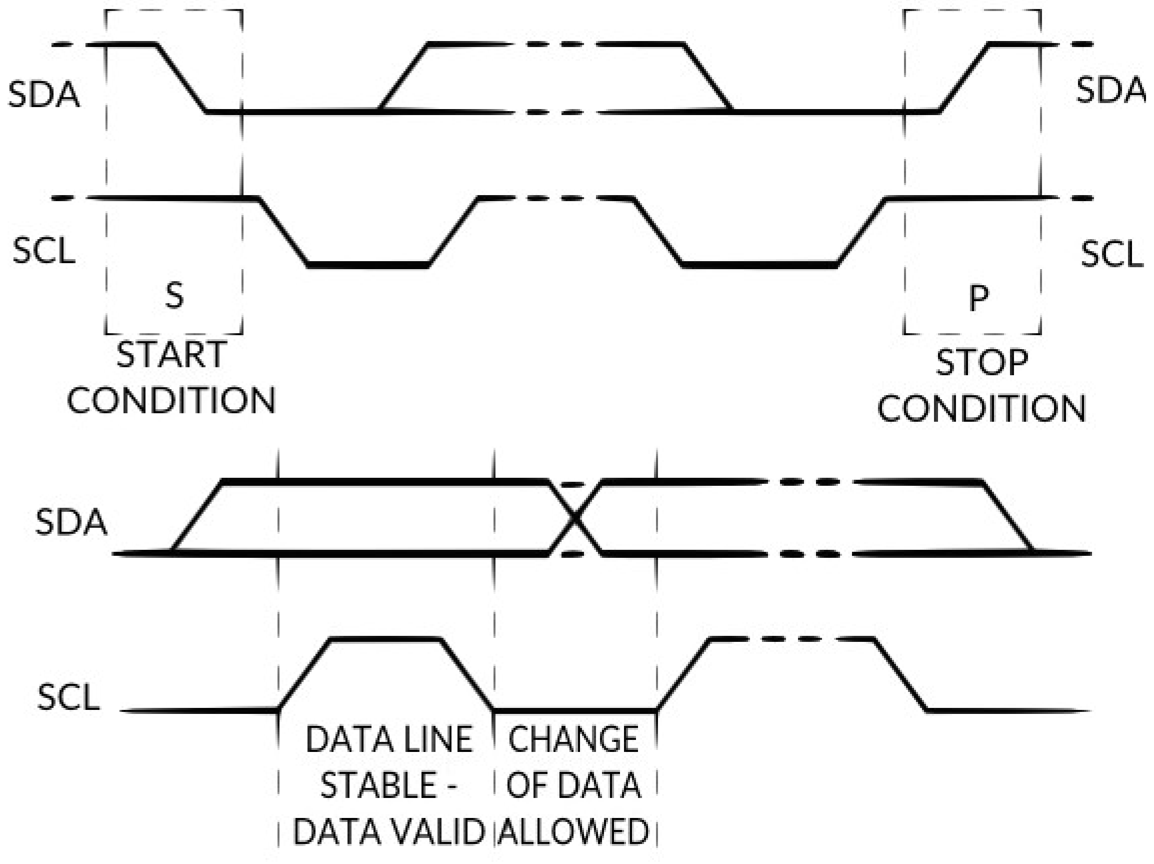
First, the master will issue a START condition. This acts as an ‘Attention’ signal to all of the connected devices. All ICs on the bus will listen to the bus for incoming data.

Then the master sends the ADDRESS of the device it wants to access, along with an indication whether the access is a Read or Write operation (Write in our example). Having received the address, all IC’s will compare it with their own address. If it doesn’t match, they simply wait until the bus is released by the stop condition (see below). If the address matches, however, the chip will produce a response called the ACKNOWLEDGE signal.

Once the master receives the acknowledge, it can start transmitting or receiving DATA. In our case, the master will transmit data. When all is done, the master will issue the STOP condition. This is a signal that states the bus has been released and that the connected ICs may expect another transmission to start any moment.

When a master wants to receive data from a slave, it proceeds the same way, but sets the RD/nWR bit at a logical one. Once the slave has acknowledged the address, it starts sending the requested data, byte by byte. After each data byte, it is up to the master to acknowledge the received data (refer to figure 5).

START and STOP are unique conditions on the bus that are closely dependent of the I²C bus physical structure. Moreover, the I²C specification states that data may only change on the SDA line if the SCL clock signal is at low level; conversely, the data on the SDA line is considered as stable when SCL is in high state (refer to figure 6 hereafter).



– Expansion to 10-bits device addressing

Any I²C device must have a built-in 7 bits address. In theory, this means that there would be only 128 different I²C devices types in the world. Practically, there are much more different I²C devices and it is a high probability that 2 devices have the same address on a I²C bus. To overcome this limitation, devices often have multiple built-in addresses that the engineer can chose through external configuration pins on the device. The I²C specification also foresees a 10-bits addressing scheme in order to extend the range of available devices address.

Practically, this has got the following impact on the I²C protocol (refer to figure 7):

– Two address words are used for device addressing instead of one.

– The first address word MSBs are conventionally coded as “11110” so any device on the bus is aware the master sends a 10 bits device address.

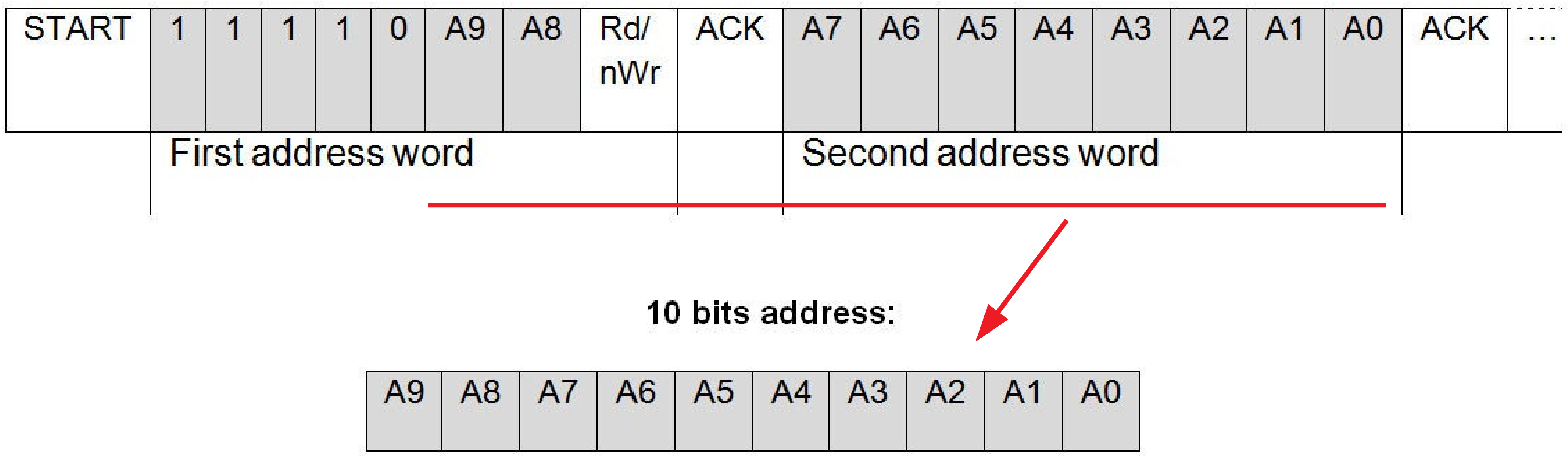
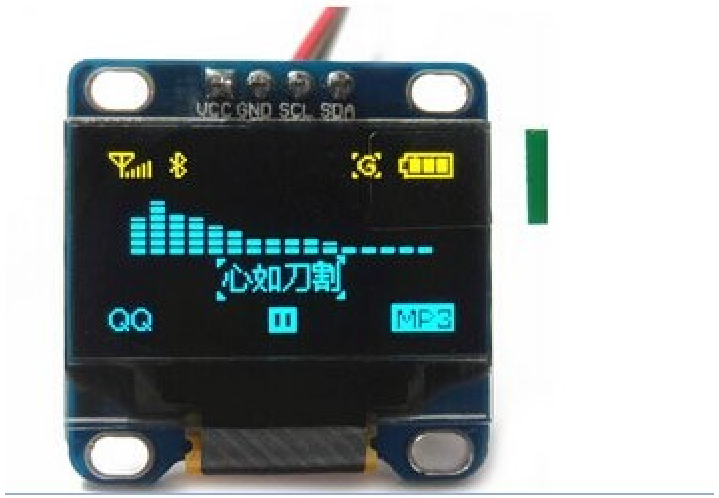


Figure 7: I²C 10-bits addressing. A 10-bits address is split into 2 words. The first word contains a conventional code on its 5 most significant bits to mark a 10-bits address, followed by the 2 MSBs of the 10-bits address and the Rd/nWR bit. The second address word contains the 8 least significant bits of the 10-bits address. This addition ensures backward compatibility with the 7-bits addressing scheme.



SSD1306

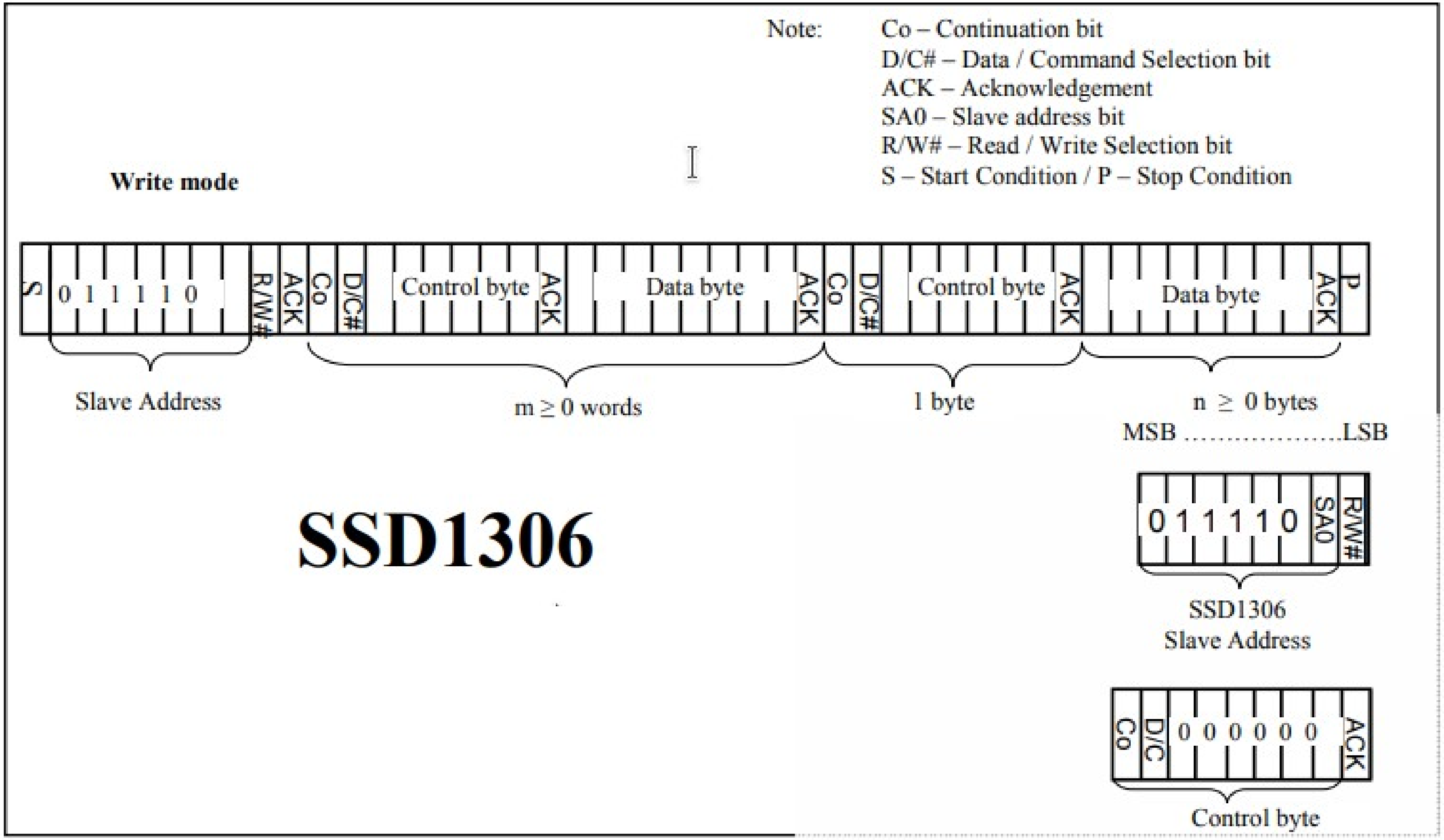
Advance Information

128 x 64 Dot Matrix
OLED/PLED Segment/Common Driver with Controller

https://cdn-shop.adafruit.com/datasheets/SSD1306.pdf

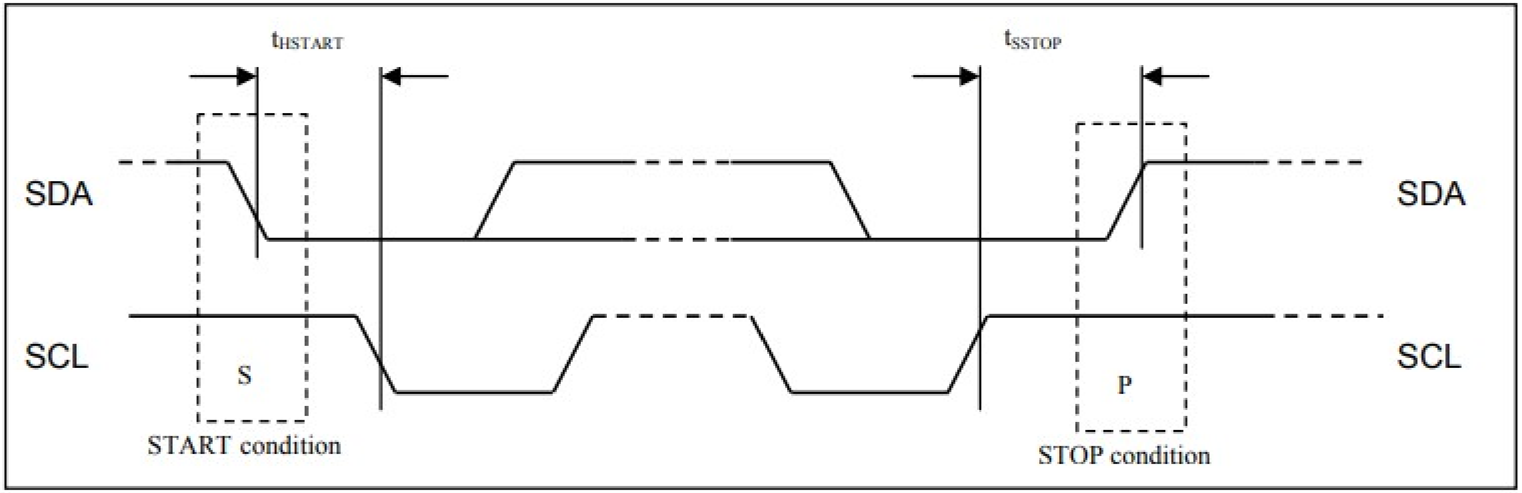
http://robotcantalk.blogspot.com/2015/03/interfacing-arduino-with-ssd1306-driven.html

Figure 8-7 : I^{2}C-bus data format



SSD1306

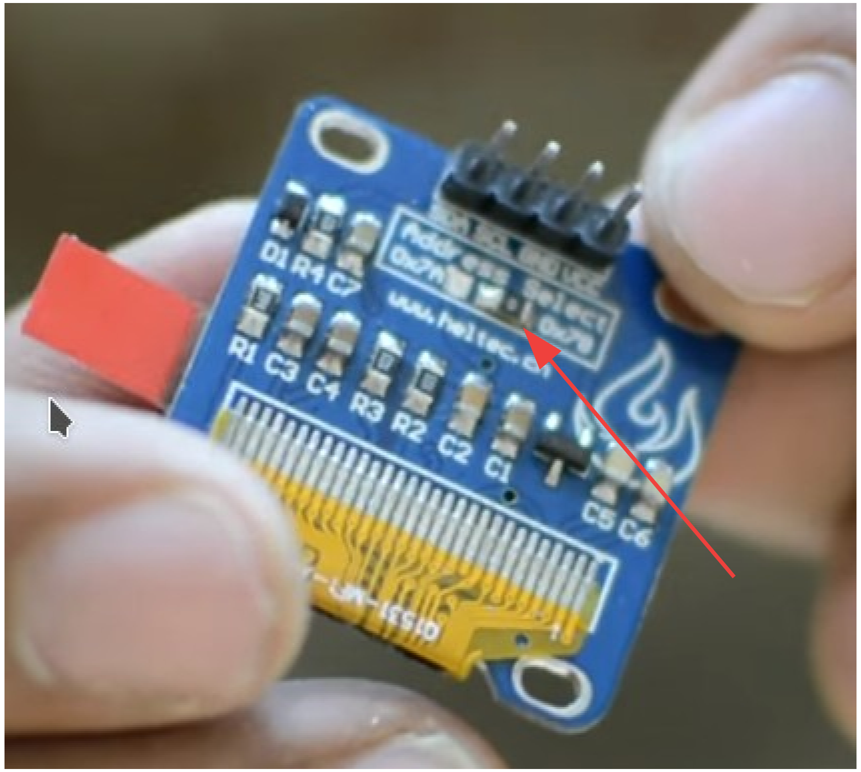
Figure 8-8 : Definition of the Start and Stop Condition



Write Mode - is the only mode for the display. So, the MSP430 is going to be the I2C master and the OLED, the I2C slave. As per the protocol, after the start condition, the Slave Address (SLA) needs to be sent.

SSD1306 Slave Adress (SLA) is 0x3C

The back of the PCB shows that the 0x78 jumper has been soldered. The sheet says that the slave adress is a 7-bit code that can be either 0x3C (011-1100) or 0x3D (011-11001), based on the SAO bit (LSB of the adress). The SAO bit can be controlled by the D/C# pin of the SSD1306 (not to be confused with the D/C# bit of the control byte in the above image!). They have soldered the pin to GND. Moreover, since, the OLED will always be interfaced in WRITE mode, the I2C First Byte will be the 7-bit SLA and the WRITE mode bit (0) - which becomes the byte, 0x78.

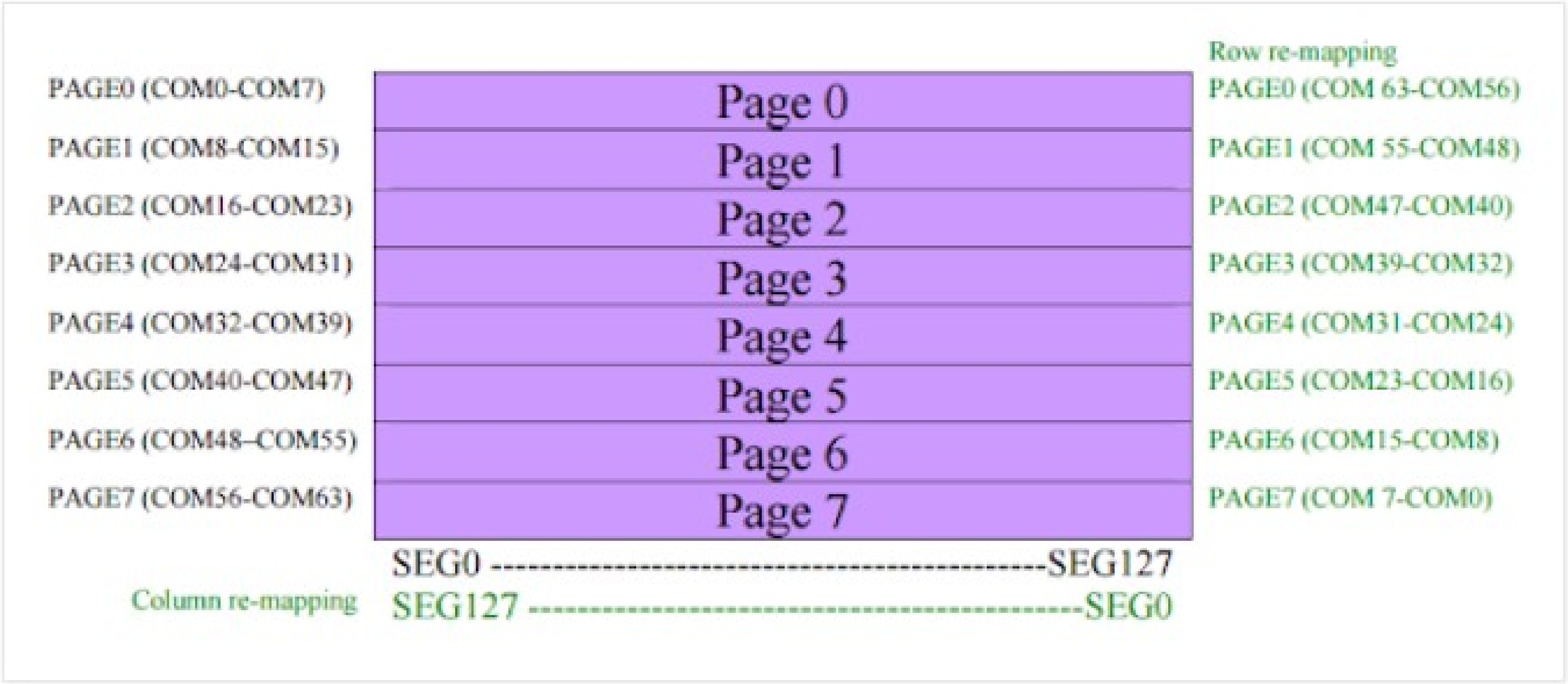


After sending the SLA+Mode byte, in order to do anything with the OLED, a `Control Byte` needs to be sent. The Control Byte determines whether the upcoming bytes would be treated as Data (which is written directly to the GDDRAM) or as Commands (to the internal MCU). Also controls the length of the upcoming bytes - single or stream (multiple bytes to received by the SSD1306 until I2C Stop condition).

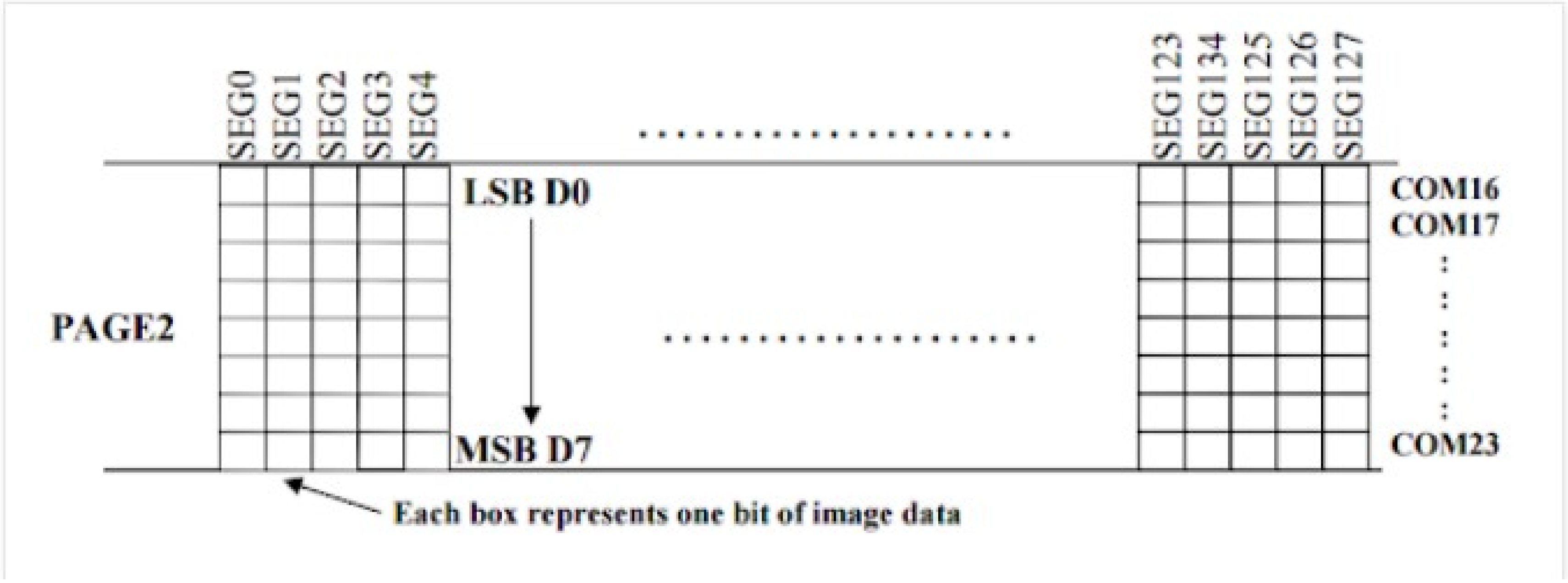
Control Byte

Deciphering this took some trial and error and real slooooow reading of section 8.1.5.2 (Writing mode for I2C) point 5. The Control Byte has these
`Co` : bit 8 : Continuation Bit
* **1** = no-continuation (only one byte to follow)
* **0** = the controller should expect a stream of bytes.
`D/C#` : bit 7 : Data/Command Select bit
* **1** = the next byte or byte stream will be Data.
* **0** = a Command byte or byte stream will be coming up next.
Bits 6-0 will be all zeros.
Usage:
`0x80` : Single Command byte
`0x00` : Command Stream
`0xC0` : Single Data byte
`0x40` : Data Stream

OLED has an 128x64 SRAM driven display with 64 rows divided as 8 Pages and 128 Columns.



Each `PAGE` will have 8 rows (COM pins) and 128 byte-sized column fractions called `SEGMENT`. The whole mapping is fully customizable, ie: You can rearrange the COM/COL assignment to have the xy(0,0) at any corner. The GDDRAM is divided into Pages to allow easy writing of character sized sprites. That means you can also use this OLED as a 8-line character display by default.



http://www.diymalls.com/OLED/0.96-blue-and-yellow-oled-display

For 0.96 inch: 0.96 inch use SSD1306 drive chip. Copy "Adafruit_SSD1306.h" and "Adafruit_GFX.h" into "x:\arduino-1.X.X\libraries".

In order to reduce the pins' number, we use a hardware RESET system. So the standard library form Adafruit or u8glib may not very suitable. Make sure you are using our provided libraries, It's very important. If those files already in you libraries, replace it.

You can download our SSD1306 OLED display Arduino library from github which comes with example code. The library can print text, bitmaps, pixels, rectangles, circles and lines. It uses 1K of RAM since it needs to buffer the entire display but its very fast!
The code is simple to adapt to any other microcontrolle

https://libraries.io/github/adafruit/Adafruit-GFX-Library

Document link: http://www.diymalls.com/files/IIC_OLED.zip
user name and password is diymall

The drivers for these two displays are very different. The monochrome SSD1306 does not have direct access to the display memory, so we have to write to an in-memory frame-buffer, then use that to refresh the screen. Clearing the display is as simple as doing a memset on the entire frame buffer in SRAM - but that only clears the frame buffer. You need to call display() to actually upload the cleared buffer to the display.

So the problem now is the Adafruit_SSD1306 library with its heavy SRAM use of 1KB for the display buffer.

https://www.best-microcontroller-projects.com/ssd1306.html

https://github.com/olikraus/u8g2/wiki/u8g2reference

Examples:

M14 – Example 1 – just light up the display – Initialization details

M14 – Example 2 – alternating test patterns

M14 – Example 3 – Grove graphics test demo

M14 – Example 4 – oledApp test demo

These programs show the complicated initialization command sequence required by the SSD 1306 and OLED

They also show code segments that are examples which can be used in application programs

Examples 1 & 2 talk directly through the USCB0 software, 3 & 4 use the Energia Wire library - YMMV