

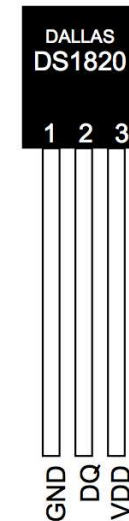
DS18B20

Programmable Resolution 1-Wire Digital Thermometer

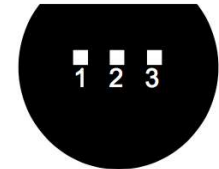
Digital Thermometer

- Unique 1-Wire interface requires only one port pin for communication
- Multidrop capability simplifies distributed temperature sensing applications
- Requires no external components
- Can be powered from data line. Power supply
- range is 3.0V to 5.5V
- Zero standby power required
- Measures temperatures from -55°C to $+125^{\circ}\text{C}$. Fahrenheit equivalent is -67°F to $+25$
- $\pm 0.5^{\circ}\text{C}$ accuracy from -10°C to $+85^{\circ}\text{C}$
- Thermometer resolution is programmable from 9 to 12 bits
- Converts 12-bit temperature to digital word in 750 ms (max.)

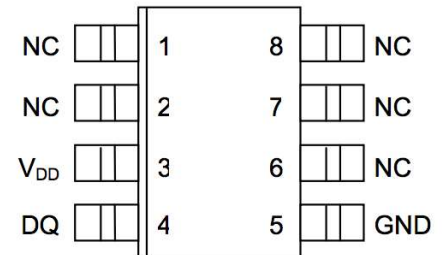
PIN ASSIGNMENT



BOTTOM VIEW



DS18B20 To-92
Package



DS18B20Z
8-Pin SOIC (150 mil)

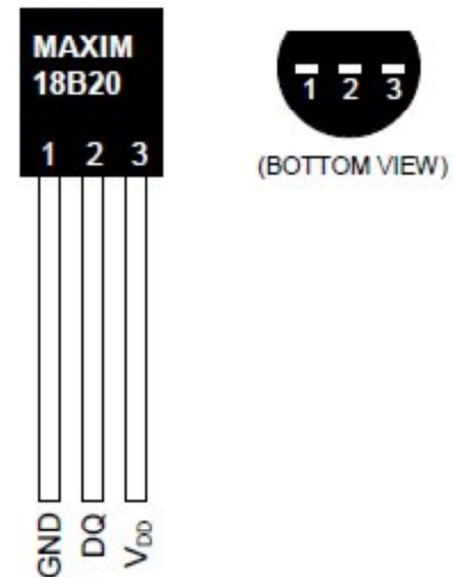
PIN DESCRIPTION

GND - Ground
DQ - Data In/Out
V_{DD} - Power Supply Voltage
NC - No Connect

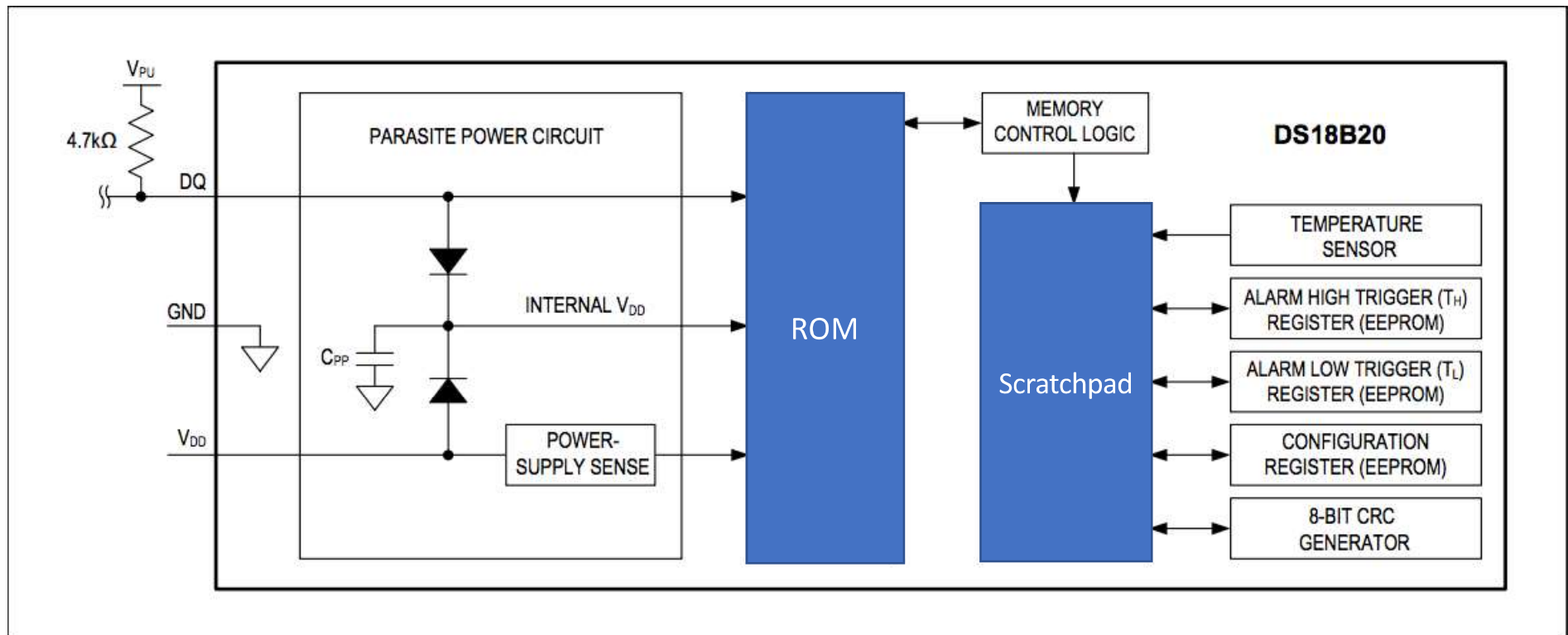
One Wire Communication

- 透過DQ以及時序的搭配來達到input以及output都透過一條線即可

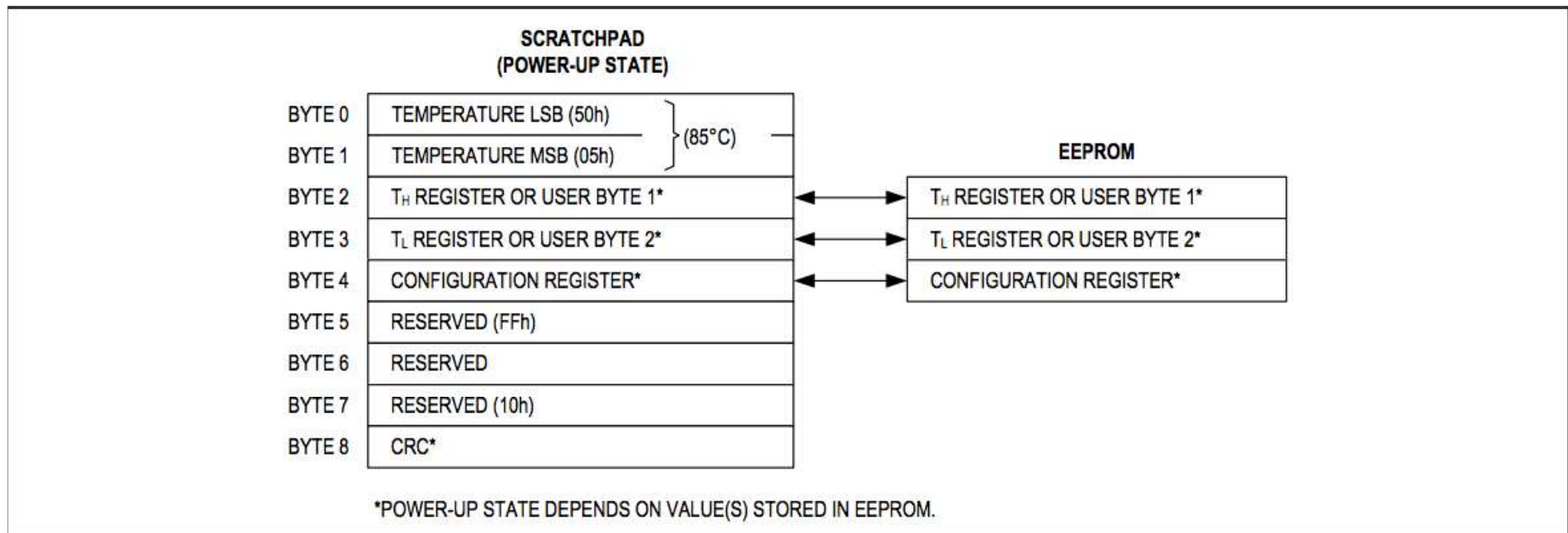
With the cooperation with DQ and time serial, it can achieve using one wire for input and output.



Block Diagram



Scratchpad Memory



Temperature Representation

	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
LS BYTE	2^3	2^2	2^1	2^0	2^{-1}	2^{-2}	2^{-3}	2^{-4}
	BIT 15	BIT 14	BIT 13	BIT 12	BIT 11	BIT 10	BIT 9	BIT 8
MS BYTE	S	S	S	S	S	2^6	2^5	2^4

S = SIGN

特性 (Feature)

- 64-bit ROM 儲存裝置的特別辨識碼（以便識別多個溫度計）
- Scratchpad 擁有 2-byte 溫度暫存器、警示暫存器（過高溫或是過低溫）及設定暫存器（精度設定），後三者為與 EEPROM 溝通所以是非揮發的。
- 溫度精度可以調成為 9 bits, 10 bits, 11 bits 及 12 bits
 - 分別為 0.5, 0.25, 0.125 及 0.0625
 - 預設為 12 bits

1. The identification code of 64-bit ROM storage.

2. Scratchpad has the 2-byte temperature, warning(overheating.. etc), setting(precision) registers. The last three registers are non-volatile because they communicate with EEPROM.

3. Precision can adjust to 9bits(0.5), 10bits(0.25), 11bits(0.125), 12bits(0.0625). Default is 12bits.

控制流程

(An operation need to go through the three steps.)

- 每次要完成一個**Operation**都必須經過三個步驟
 - Initialization
 - ROM Command
 - DS18B20 Function Command

Initialization

- 透過 One Wire Protocol 告訴 DS18B20 我們準備要下指令給它了

Through One Wire Protocol tell DS18b20 we're going to set instruction.

ROM Command

- 若同時在匯流排上有很多 DS18B20 我們可以透過 ROM Command 來找尋特定的 DS18B20。
- 也可以用來偵測是否有任一 Device 有超溫或是溫度過低的現象。
 - Search ROM [0xF0]
 - Read ROM [0x33]
 - Match ROM [0x55]
 - Skip ROM [0xCC]
 - Alarm Search [0xEC]
- 若只有一個 DS18B20，我們可以使用 Skip ROM 這個指令

1. We can use ROM command to search specific DS18B20 if there're lots of DS18B20 on the bus at same time.
2. It can also detect is there any device's temperature too high or too low.
3. If just has one DS18B20, we can use Skip ROM instruction.

DS18B20 Function Command

These commands are used to read/write Scratchpad Memory.

- 這些指令是用來讀寫 Scratchpad Memory 的。
 - Convert T [0x44]
 - Write Scratchpad [0x4E]
 - Read Scratchpad [0xBE]
 - Copy Scratchpad [0x48]
 - Recall E^2 [0xB8]
 - Read Power Supply [0xB4]

Convert T[emperature]

- 開始讀取環境溫度並且利用ADC轉換
- 溫度將會放在 Scratchpad Memory 的前兩個 byte
- 不同精度需要不同的轉換時間
 - 9-bit -> 93.75 ms
 - 10-bit -> 187.5 ms
 - 11-bit -> 375 ms
 - 12-bit -> 750 ms
- 若轉換完成後，透過one wire 讀取一個 bit 會得到 1，反之則代表還正在進行溫度轉換。

1. Start detecting the temperature and use ADC to transform.
2. Temperature will be put on the first two byte of Scratchpad Memory.
3. The transformation time is shown above.
4. If finish transformation, you will read 1 from one wire. Otherwise it just still transforming.

Write Scratchpad

- 分別寫入 3 bytes 的資料到 Scratchpad 裡

- T_H : 高溫 threshold
- T_L : 低溫 threshold
- Configuration:

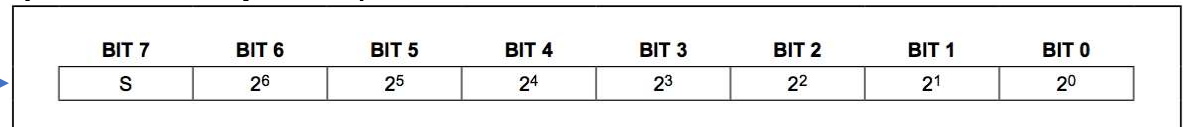


Figure 5. T_H and T_L Register Format

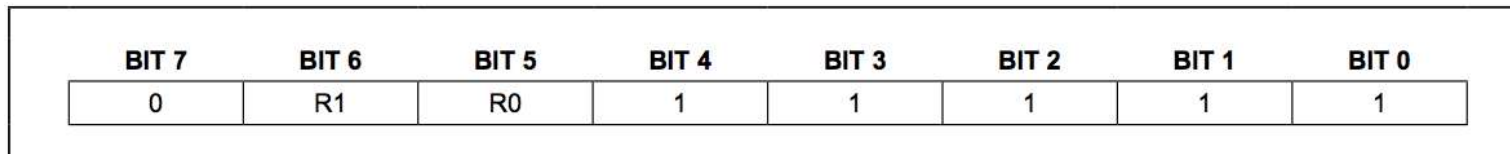


Figure 10. Configuration Register

Table 2. Thermometer Resolution Configuration

R1	R0	RESOLUTION (BITS)	MAX CONVERSION TIME	
0	0	9	93.75ms	($t_{CONV}/8$)
0	1	10	187.5ms	($t_{CONV}/4$)
1	0	11	375ms	($t_{CONV}/2$)
1	1	12	750ms	(t_{CONV})

Copy Scratchpad

- 將 T_H , T_L 及 Configuration 從 Scratchpad Memory 寫到 EEPROM 裡面（非揮發性記憶體）。

Using T(H), T(L) and Configuration write Scratchpad Memory to EEPROM(non-volatile).

Recall E²

- 將 T_H , T_L 及 Configuration 從 EEPROM（非揮發性記憶體）讀到 Scratchpad Memory 裡面。

Writing T(H), T(L), Configuration from EEPROM(non-volatile) to Scratchpad Memory.

Read Power Supply

- 若接線方式為 Parasitic Mode (寄生方式)，則在 one wire 1-bit 讀取時會拿到 low
- 若接線方式為 External Power Supply，則在 one wire 1-bit 讀取時會拿到 high

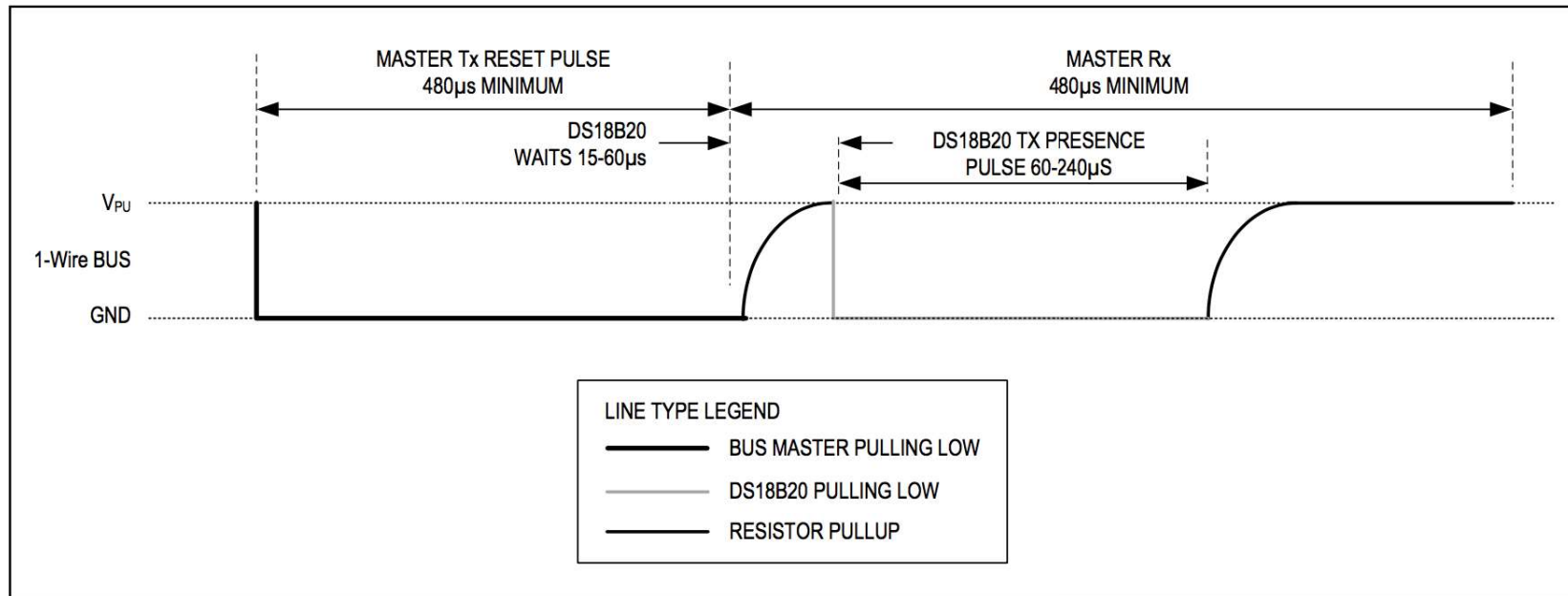
1. If we using Parasitic Mode to wiring your circuit, you will get low when read one wire 1-bit.
2. If we using External Power Supply to wiring your circuit, you will get high when read one wire 1-bit.

One Wire Protocol (Initialization)

- Master 把電壓壓低(0)最少 480 us
- Master 釋放 wire（改成input）並且因為pull-up resistor所以會電壓拉高
- 當 DS18B20 偵測到正緣，它會等待 15us 到 60us 然後把電壓壓低 60us 到240us
- 當我們偵測到 DS18B20 有把電壓壓低，我們便知道 DS18B20 已經初始化了

1. Master keeps the low voltage(0 voltage) at least 480 us.
2. Master releases wire(change to input) and because pull-up resistor it will trigger the high voltage.
3. When DS18B20 detect the Positive edge, it will wait 15 to 60 us and trigger the voltage to low 60 to 240 us.
4. When we detect the DS18B20 trigger the voltage to low, we know that it finish initializatoin.

One Wire Protocol (Initialization)

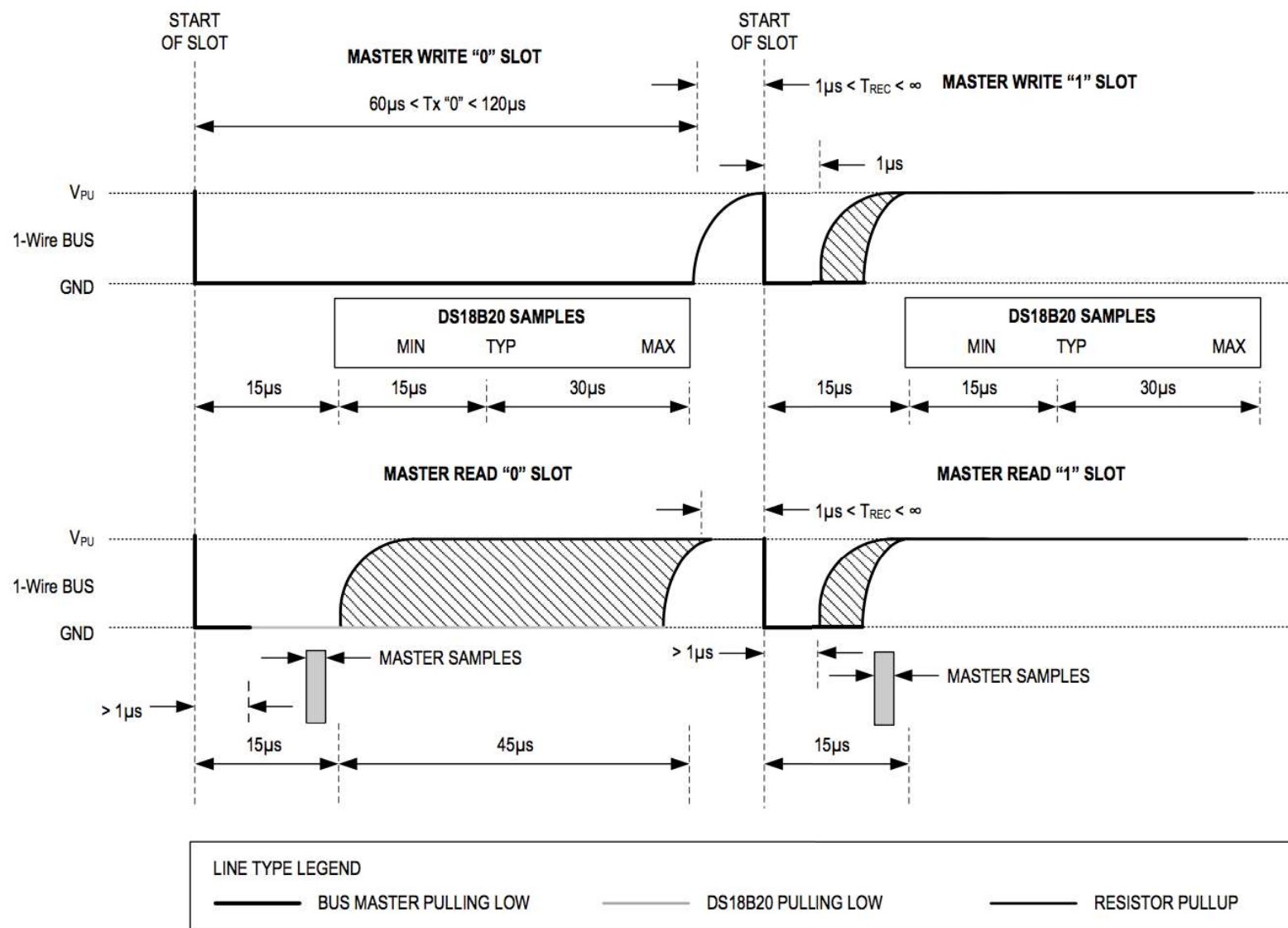


```
uint8_t OneWire_Reset(OneWire_t* OneWireStruct) {  
    ...  
  
    /* Line low, and wait 480us */  
    ONEWIRE_INPUT(OneWireStruct);  
    ONEWIRE_LOW(OneWireStruct);  
    ONEWIRE_OUTPUT(OneWireStruct);  
    ONEWIRE_DELAY(480);  
  
    /* Release line and wait for 70us */  
    ONEWIRE_INPUT(OneWireStruct);  
    ONEWIRE_DELAY(70);  
  
    /* Check bit value */  
    ...  
  
    /* Delay for 410 us */  
    ONEWIRE_DELAY(410);  
  
    ...  
}
```

One Wire Protocol (Read 1 bit)

- 每一次的 read operation 最少都要有 60us
- 連續兩次之間要間格最少 1us
- 由 Master 把 DQ 拉低最少 1us 然後釋放DQ(改成input) 表示開始讀取。
- DS18B20 將會開始放 0 (low) 或是 1 (high) 在DQ上
- DS18B20 所送出來的 data 只會有效 15us （從Master把DQ拉低開始算），也就是說，Master 必須要在 15us 內把值讀進來

1. Every read operation need at least 60 us.
2. You need to put at least 1us waiting between two operation.
3. Master trigger the DQ to low at least 1us and release the DQ(change to input) -> start reading.
4. DS18B20 will start put 0(low) or 1(high) on the DQ.
5. The data sent by the DS18B20 only stay 15us(count from Master trigger the DQ), so you need to read it in 15us.



One Wire Protocol (Write 1 bit)

- 每一次的 write operation 最少都要有 60us
- 連續兩次之間要間格最少 1us
- Master Write 1
 - 由 Master 把 DQ 拉低
 - 15us 內釋放DQ(改成input)
- Master Write 0
 - 由 Master 把 DQ 拉低
 - 維持至少 60us

1. Every write operation need at least 60us.
2. You need to put at least 1us waiting between two operation.
3. Master trigger the DQ to low and release(change to input) in 15us -> Write 1.
4. Master trigger the DQ to low and keep at least 60 us -> Write 0.

One Wire Protocol (Note)

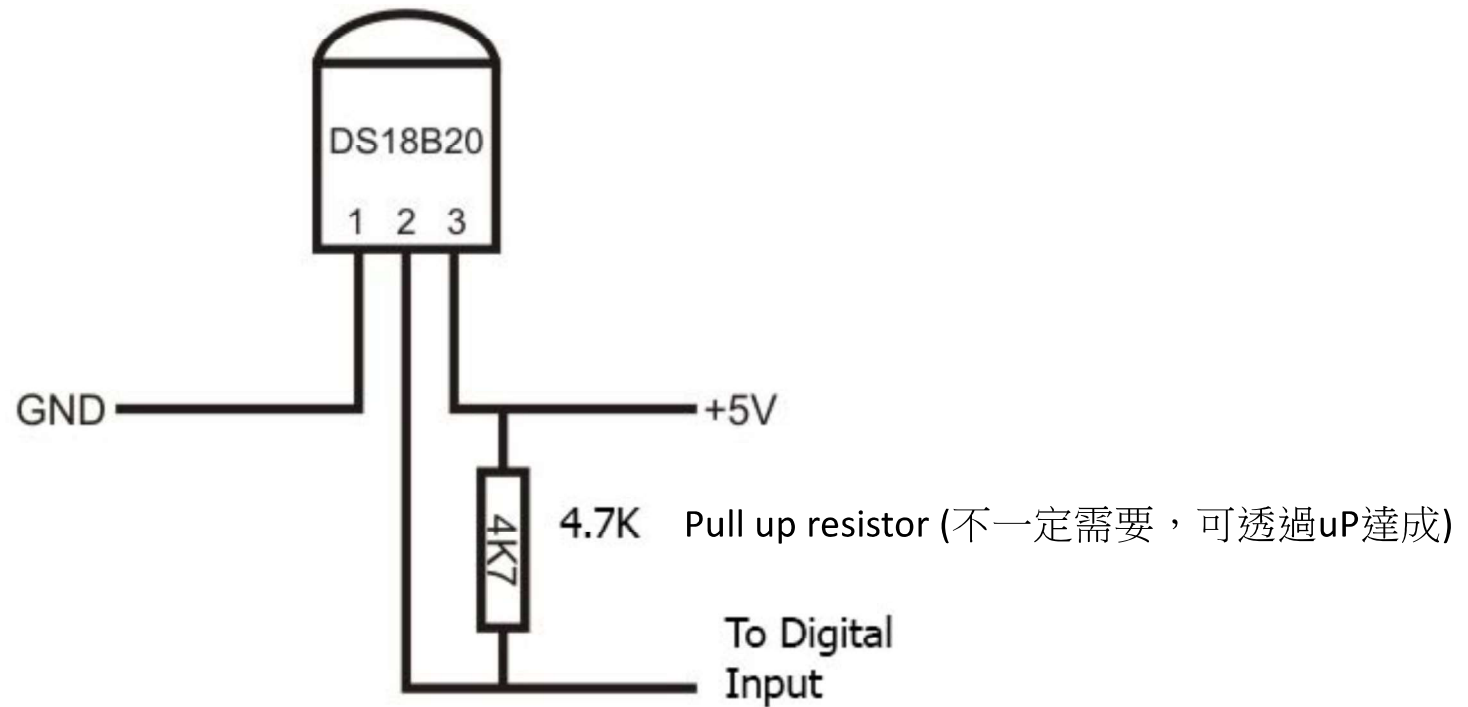
- 所有的 **Operation** 都是透過負緣觸發（從高電位變成低電位的時候），因此請注意原本的電位。
- 由於 DQ 有接一個 Pull-up resistor，若將 DQ 設置為 input 時，空角位的狀態會是 high，也就是當對方沒有給任何 input 時則為 high，當對方給 low 時，則為 low，對方給 high 時，還是 high

1. All the operations is triggered by negative edge, so you need to pay attention to your original voltage.
2. Because DQ has a Pull-up resistor, so when set DQ as input if no one give DQ input it will be high. Otherwise it will be 0 and 1 when input is 0 and 1.

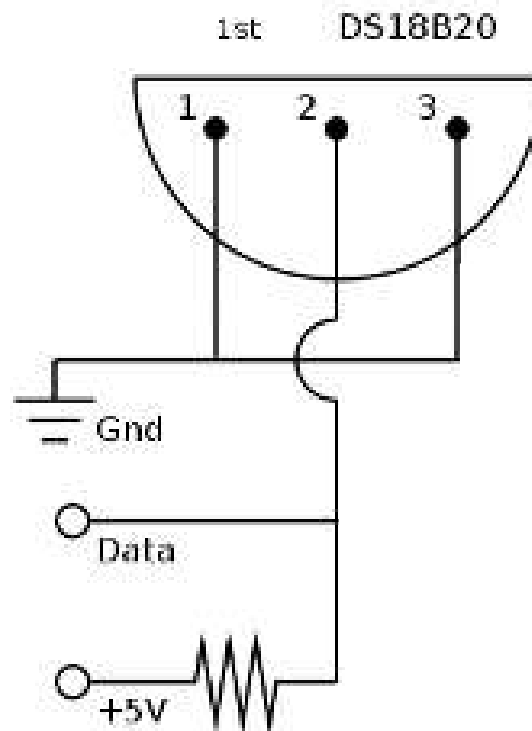
```
void OneWire_WriteBit(OneWire_t* OneWireStruct, uint8_t bit) {
    ONEWIRE_INPUT(OneWireStruct);
    if (bit) {
        /* Set line low */
        ONEWIRE_LOW(OneWireStruct);
        ONEWIRE_OUTPUT(OneWireStruct);
        ...

        /* Bit high */
        ONEWIRE_INPUT(OneWireStruct);
        ...
    } else {
        /* Set line low */
        ONEWIRE_LOW(OneWireStruct);
        ONEWIRE_OUTPUT(OneWireStruct);
        ...
    }
    ONEWIRE_INPUT(OneWireStruct);
}
```


接線 (External Power Supply)



接線 (Parasitic Mode)



Reference

- <http://datasheets.maximintegrated.com/en/ds/DS18B20.pdf>
(Datasheet)