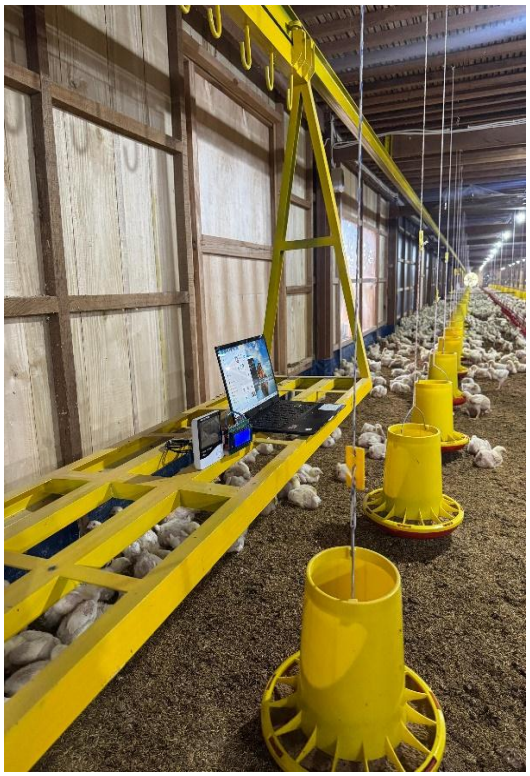
LAMPIRAN

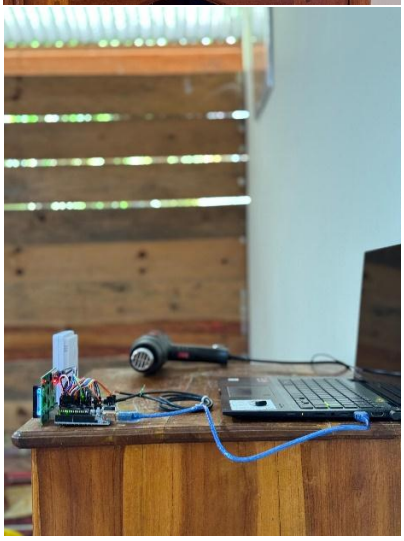

TEMPERATURE
CLOCK / HUMIDITY
HTC-1

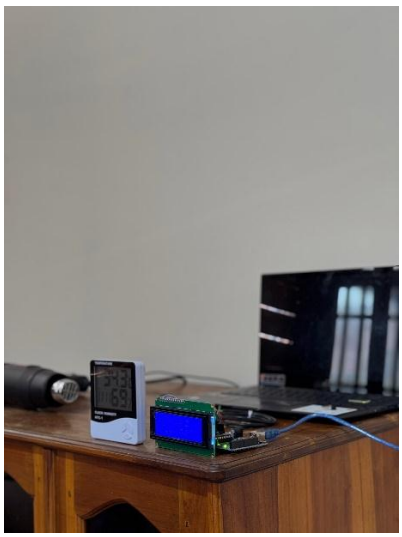


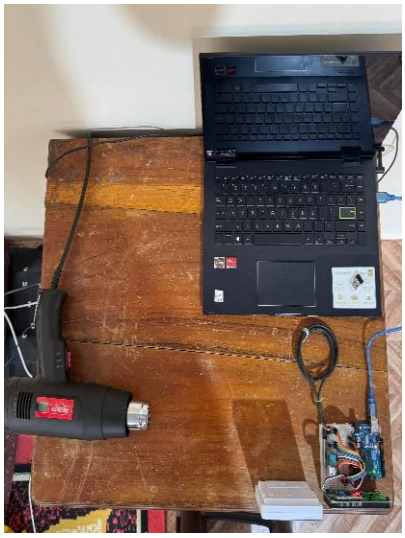












a. Sketch Pengujian Sensor Suhu DHT22

```
#include <Wire.h>
#include "DHT.h"
#define DHTPIN_22  A3
#define DHTTYPE_22 DHT22
DHT dht_22(DHTPIN_22, DHTTYPE_22);
float t_22;

void setup()
{
  Serial.begin(9600);
  pinMode(DHTPIN_22, INPUT);
  dht_22.begin();
}

void loop()
{
    t_22 = dht_22.readTemperature();
    // kesalahan baca
    if (isnan(t_22))
      {
        Serial.println(F("Failed to read from DHT 22 sensor!"));
        return;
      }
   Serial.println(t_22);
   delay(500);
}
```

b. Sketch Pengujian Sensor Suhu DHT11

```
#include <Wire.h>
#include "DHT.h"
#define DHTPIN_11  A2
#define DHTTYPE_11 DHT11
DHT dht_11(DHTPIN_11, DHTTYPE_11);
float t_11;

void setup()
{
  Serial.begin(9600);
  pinMode(DHTPIN_11, INPUT);
  dht_11.begin();
}

void loop()
{
  t_11 = dht_11.readTemperature();
  // kesalahan baca
  if (isnan(t_11))
    {
      Serial.println(F("Failed to read from DHT 22 sensor!"));
      return;
    }
  Serial.println(t_11);
  delay(500);
}
```

c. Sketch Pengujian Sensor Suhu LM35

```
#include <Wire.h>
#define lm35Pin A1
int lm35suhu1;
float lm35Suhu;

void setup() {
  Serial.begin(9600);
  pinMode(lm35Pin, INPUT);
}

void loop()
{
  /*-------------------------------------------------------------------------
  1'C = 10mV (sesuai datasheet)
  5v /1023 = 4,883 mV (5v = tegangan refrensi, 1023 = resolusi 10 bit)
  setiap kenaikan 1'C --> 10 / 4.883 = 2.0479
  sehingga didapat rumus lm35Suhu = lm35suhu1 / 2.0479;
  -------------------------------------------------------------------------*/
  lm35suhu1 = analogRead(lm35Pin);
  lm35Suhu = lm35suhu1 / 2.0479;
  Serial.println(lm35Suhu);
  delay(500);
}
```

- Sketch Pengujian Sensor Suhu DS18B20

```
#include <OneWire.h>
#include <DallasTemperature.h>
OneWire oneWire(ds18b20Pin);
#define ds18b20Pin A0
DallasTemperature DS18B20(&oneWire);

void setup() {
  Serial.begin(9600);
  pinMode(ds18b20Pin, INPUT);
  DS18B20.begin();
}

void loop()
{
  DS18B20.requestTemperatures();
  DS18B20Suhu = DS18B20.getTempCByIndex(0);
  Serial.println(DS18B20Suhu);
  delay(500);
}
```

d. Sketch Pembacaan Suhu DHT22, DHT11, LM35, dan DS18B20

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd(0x27,20,4);
//-------------------------------------------------------
#include "DHT.h"
#define DHTPIN_22  A3
#define DHTPIN_11  A2
#define lm35Pin    A1
```

```
#define ds18b20Pin A0

#define DHTTYPE_11 DHT11
#define DHTTYPE_22 DHT22

DHT dht_11(DHTPIN_11, DHTTYPE_11);
DHT dht_22(DHTPIN_22, DHTTYPE_22);

float t_11;
float t_22;
int lm35suhu1;
float lm35Suhu;
float DS18B20Suhu;
//---------------------------------------------------------
#include <OneWire.h>
#include <DallasTemperature.h>
OneWire oneWire(ds18b20Pin);
//DallasTemperature sensors(&oneWire);
DallasTemperature DS18B20(&oneWire);
void setup() {
  Serial.begin(9600);
  //---------------------------------------------------------
  pinMode(DHTPIN_22, INPUT);
  pinMode(DHTPIN_11, INPUT);
  pinMode(lm35Pin, INPUT);
  pinMode(ds18b20Pin, INPUT);
  //---------------------------------------------------------
  lcd.init();
  lcd.init();
  lcd.backlight();
  lcd.setCursor(0,0); lcd.print("Uji Sensor Suhu");
  lcd.setCursor(0,1); lcd.print("____________________");
  lcd.setCursor(0,2); lcd.print("Menyiapkan Perangkat");
  lcd.setCursor(0,3);
  for (int i=0; i<10; i++)
   {
    lcd.setCursor(i,3);
    lcd.print(".");
    delay(300);
   }
  lcd.setCursor(11,3);  lcd.print("OK !");
  delay(2000);
  lcd.clear();
  lcd.setCursor(0,0);  lcd.print("DHT22   :       C");
  lcd.setCursor(0,1);  lcd.print("DHT11   :       C");
  lcd.setCursor(0,2);  lcd.print("LM35    :       C");
  lcd.setCursor(0,3);  lcd.print("DS18b20 :       C");
  //---------------------------------------------------------
  dht_11.begin();
  dht_22.begin();
  DS18B20.begin();
}
void bacaDHT_11()
{
  t_11 = dht_11.readTemperature();
  // kesalahan baca
  if (isnan(t_11))
    {
      lcd.setCursor(10,1);  lcd.print("-");
      return;
```

```
    }
}

void bacaDHT_22()
{
  t_22 = dht_22.readTemperature();
  // kesalahan baca
  if (isnan(t_22))
    {
      Serial.println(F("Failed to read from DHT 22 sensor!"));
      return;
    }
}

void baca_LM35()
{
  /*--------------------------------------------------------------------------
  1'C = 10mV (sesuai datasheet)
  5v /1023 = 4,883 mV (5v = tegangan refrensi, 1023 = resolusi 10 bit)
  setiap kenaikan 1'C --> 10 / 4.883 = 2.0479
  sehingga didapat rumus lm35Suhu = lm35suhu1 / 2.0479;
  --------------------------------------------------------------------------*/
  lm35suhu1 = analogRead(lm35Pin);
  lm35Suhu = lm35suhu1 / 2.0479;
}

void baca_DS18b20()
{
  DS18B20.requestTemperatures();
  DS18B20Suhu = DS18B20.getTempCByIndex(0);
}

void tampilLCD()
{
  lcd.setCursor(10,0); lcd.print(t_22);
  lcd.setCursor(10,1); lcd.print(t_11);
  lcd.setCursor(10,2); lcd.print(lm35Suhu);
  lcd.setCursor(10,3); lcd.print(DS18B20Suhu);
}

void tampilSerial()
{
  Serial.print(t_22);
  Serial.print(" ");
  Serial.print(t_11);
  Serial.print(" ");
  Serial.print(lm35Suhu);
  Serial.print(" ");
  Serial.println(DS18B20Suhu);
}

void loop()
{
  bacaDHT_11();
  bacaDHT_22();
  baca_LM35();
  baca_DS18b20();
  tampilSerial();
  tampilLCD();
  delay(500);
}
```

DHT11 Humidity & Temperature

Sensor

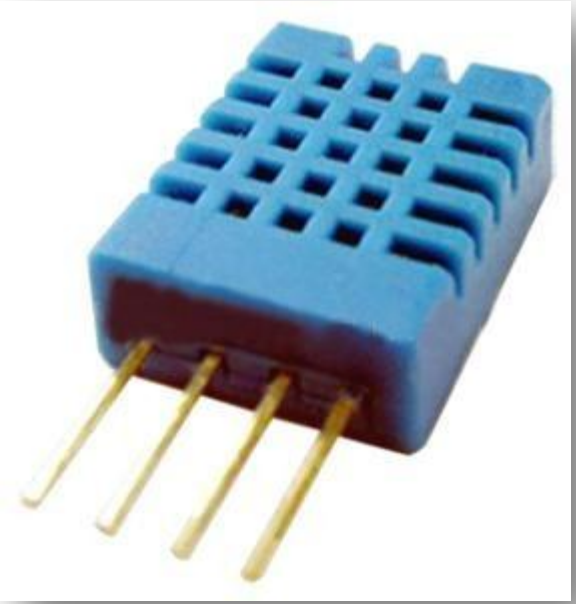
DHT11 Temperature & Humidity Sensor features a temperature & humidity sensor complex with a calibrated digital signal output.

DHT 11 Humidity & Temperature Sensor

1. Introduction

DHT11 Temperature & Humidity Sensor features a temperature & humidity sensor

complex with a calibrated digital signal output. By using the exclusive digital-signal-acquisition technique and temperature & humidity sensing technology, it ensures high reliability and excellent long-term stability. This sensor includes a resistive-type humidity measurement component and an NTC temperature measurement component, and connects to a high-performance 8-bit microcontroller, offering excellent quality, fast response, anti-interference ability and cost-effectiveness.



Each DHT11 element is strictly calibrated in the laboratory that is extremely accurate on humidity calibration. The calibration coefficients are stored as programmes in the OTP memory, which are used by the sensor's internal signal detecting process. The single-wire serial interface makes system integration quick and easy. Its small size, low power consumption and up-to-20 meter signal transmission making it the best choice for various applications, including those most demanding ones. The component is 4-pin single row pin package. It is convenient to connect and special packages can be provided according to users' request.

2. Technical Specifications:

Overview:

Item	Measurement Range	Humidity Accuracy	Temperature Accuracy	Resolution	Package
DHT11	20-90%RH 0-50 ℃	±5%RH	±2℃	1	4 Pin Single Row

Detailed Specifications:

Parameters	Conditions	Minimum	Typical	Maximum
Humidity				
Resolution		1%RH	1%RH	1%RH
			8 Bit	
Repeatability			±1%RH	
Accuracy	25°C		±4%RH	
	0-50°C			±5%RH
Interchangeability	Fully Interchangeable			
Measurement Range	0°C	30%RH		90%RH
	25°C	20%RH		90%RH
	50°C	20%RH		80%RH
Response Time (Seconds)	1/e(63%)25°C, 1m/s Air	6 S	10 S	15 S
Hysteresis			±1%RH	
Long-Term Stability	Typical		±1%RH/year	
Temperature				
Resolution		1°C	1°C	1°C
		8 Bit	8 Bit	8 Bit
Repeatability			±1°C	
Accuracy		±1°C		±2°C
Measurement Range		0°C		50°C
Response Time (Seconds)	1/e(63%)	6 S		30 S

3. Typical Application (Figure 1)

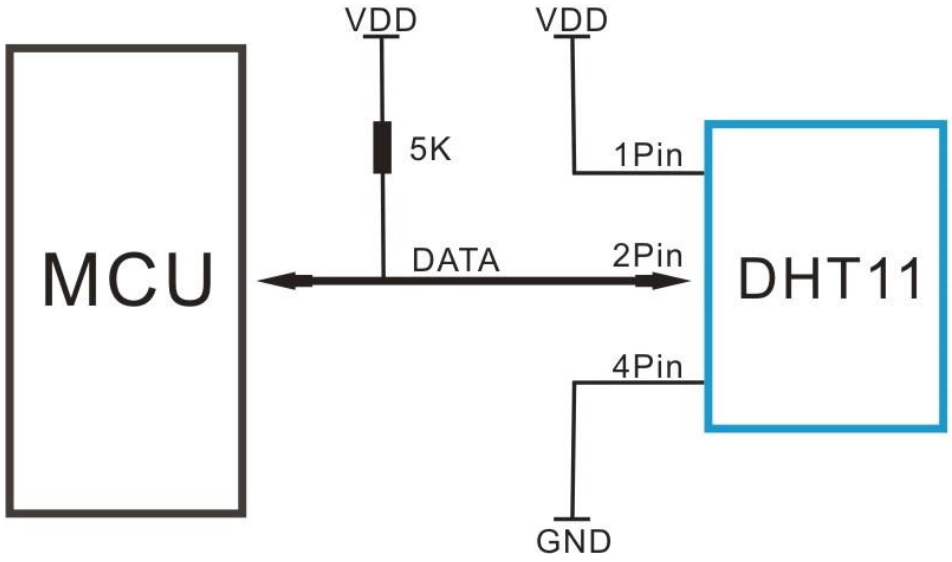


Figure 1 Typical Application

Note: 3Pin – Null; MCU = Micro-computer Unite or single chip Computer

When the connecting cable is shorter than 20 metres, a 5K pull-up resistor is recommended; when the connecting cable is longer than 20 metres, choose a appropriate pull-up resistor as needed.

4. Power and Pin

DHT11's power supply is 3-5.5V DC. When power is supplied to the sensor, do not send any instruction to the sensor in within one second in order to pass the unstable status. One capacitor valued 100nF can be added between VDD and GND for power filtering.

5. Communication Process: Serial Interface (Single-Wire Two-Way)

Single-bus data format is used for communication and synchronization between MCU and DHT11 sensor. One communication process is about 4ms.

Data consists of decimal and integral parts. A complete data transmission is **40bit**, and the sensor sends **higher data bit** first.

Data format: 8bit integral RH data + 8bit decimal RH data + 8bit integral T data + 8bit decimal T data + 8bit check sum. If the data transmission is right, the check-sum should be the last 8bit of "8bit integral RH data + 8bit decimal RH data + 8bit integral T data + 8bit decimal T data".

5.1 *Overall Communication Process (Figure 2, below)*

When MCU sends a start signal, DHT11 changes from the low-power-consumption mode to the running-mode, waiting for MCU completing the start signal. Once it is completed, DHT11 sends a response signal of 40-bit data that include the relative humidity and temperature information to MCU. Users can choose to collect (read) some data. Without the start signal from MCU, DHT11 will not give the response signal to MCU. Once data is collected, DHT11 will change to the low-power-consumption mode until it receives a start signal from MCU again.

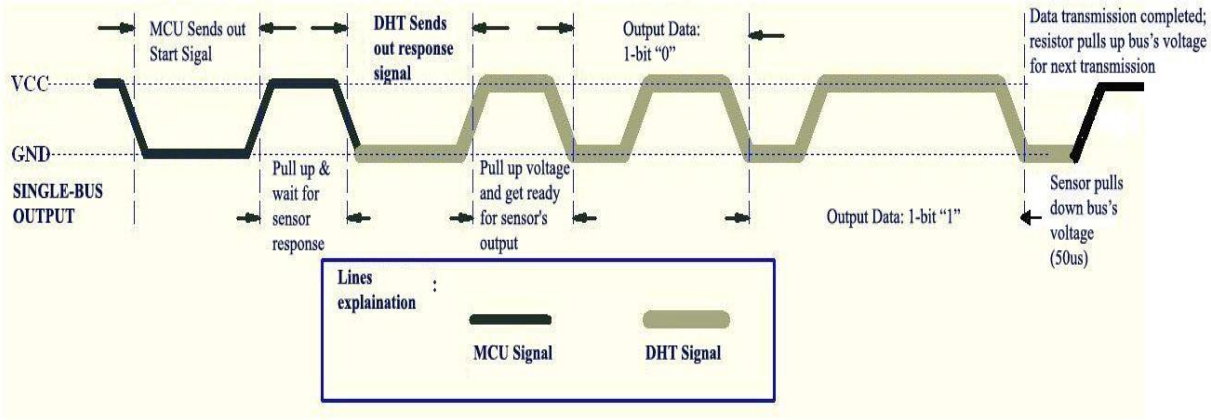


Figure 2 Overall Communication Process

5.2 *MCU Sends out Start Signal to DHT (Figure 3, below)*

Data Single-bus free status is at high voltage level. When the communication between MCU and DHT11 begins, the programme of MCU will set Data Single-bus voltage level from high to low and this process must take at least 18ms to ensure DHT's detection of MCU's signal, then MCU will pull up voltage and wait 20-40us for DHT's response.

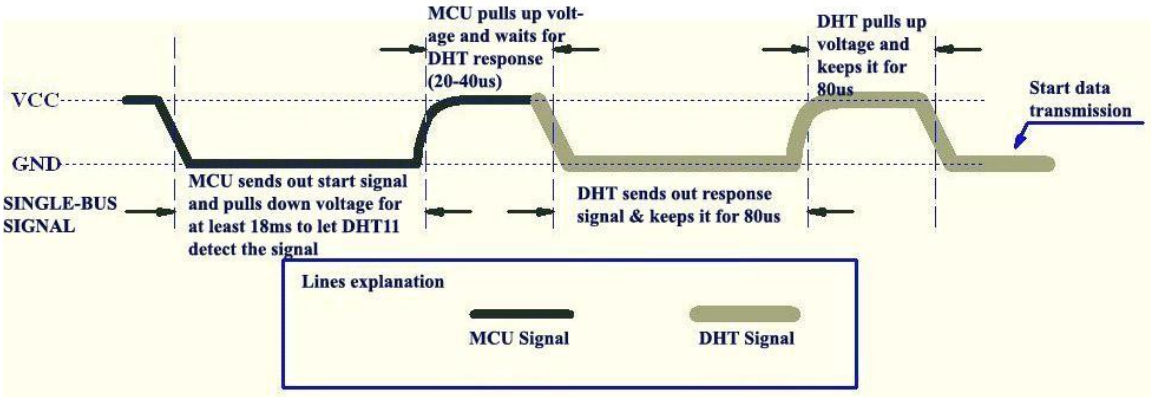


Figure 3 MCU Sends out Start Signal & DHT Responses

5.3 *DHT Responses to MCU (Figure 3, above)*

Once DHT detects the start signal, it will send out a low-voltage-level response signal, which lasts 80us. Then the programme of DHT sets Data Single-bus voltage level from low to high and keeps it for 80us for DHT's preparation for sending data.

When DATA Single-Bus is at the low voltage level, this means that DHT is sending the response signal. Once DHT sent out the response signal, it pulls up voltage and keeps it for 80us and prepares for data transmission.

When DHT is sending data to MCU, every bit of data begins with the 50us low-voltage-level and the length of the following high-voltage-level signal determines whether data bit is "0" or "1" (see Figures 4 and 5 below).

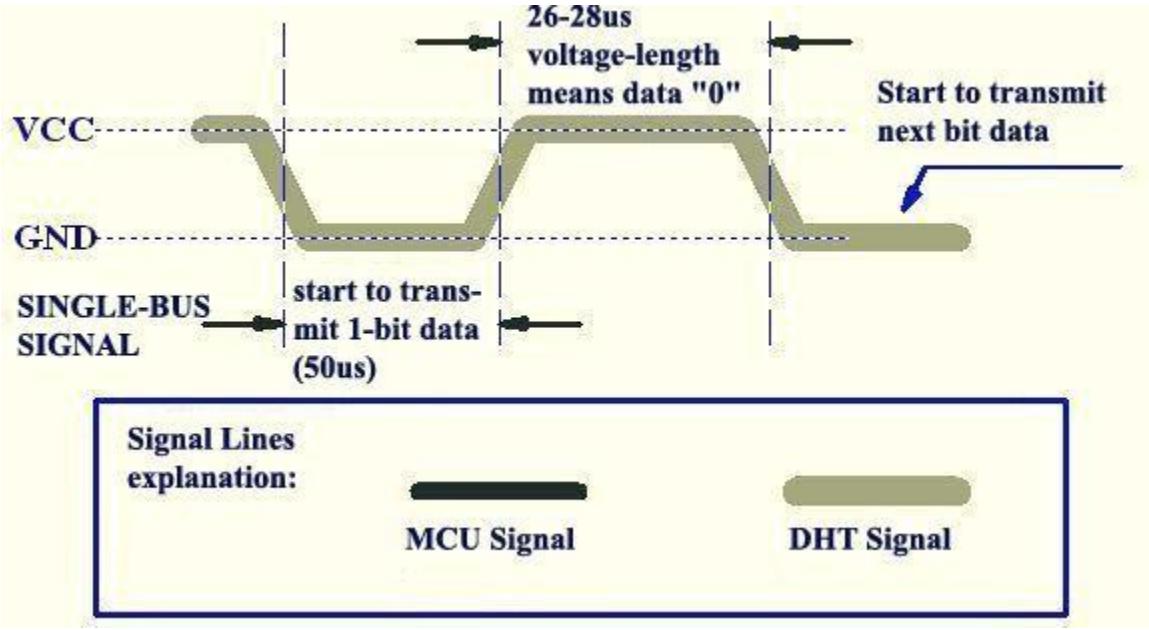


Figure 4 Data "0" Indication

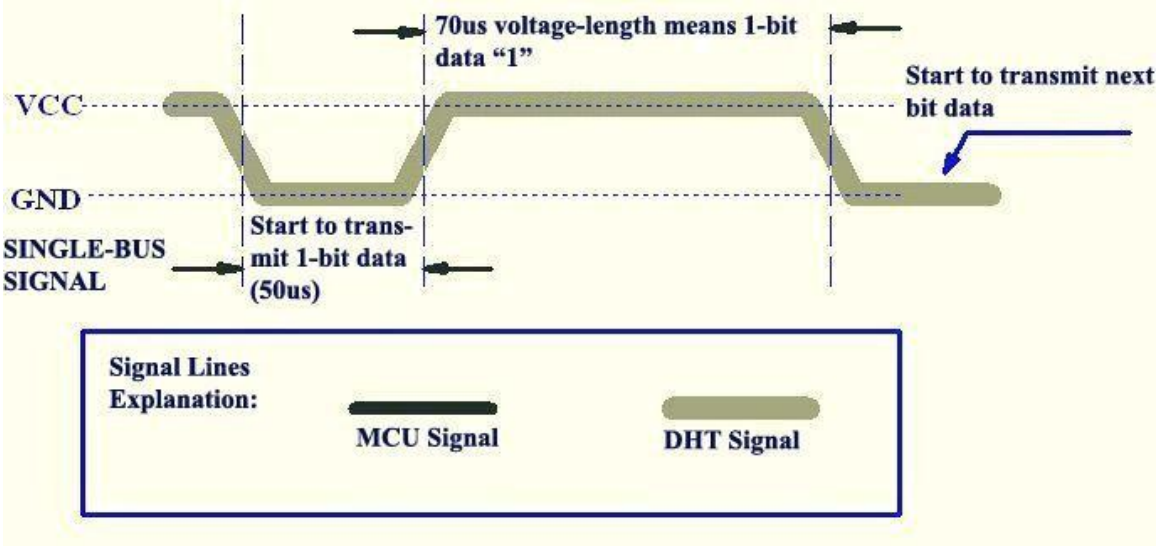


Figure 5 Data "1" Indication

If the response signal from DHT is always at high-voltage-level, it suggests that DHT is not responding properly and please check the connection. When the last bit data is transmitted, DHT11 pulls down the voltage level and keeps it for 50us. Then the Single-Bus voltage will be pulled up by the resistor to set it back to the free status.

6. *Electrical Characteristics*

VDD=5V, T = 25℃ (unless otherwise stated)

	Conditions	Minimum	Typical	Maximum
Power Supply	DC	3V	5V	5.5V
Current Supply	Measuring	0.5mA		2.5mA
	Average	0.2mA		1mA
	Standby	100uA		150uA
Sampling period	Second	1		

Note: Sampling period at intervals should be no less than 1 second.

7. *Attentions of application*

(1) Operating conditions

Applying the DHT11 sensor beyond its working range stated in this datasheet can result in 3%RH signal shift/discrepancy. The DHT11 sensor can recover to the calibrated status gradually when it gets back to the normal operating condition and works within its range. Please refer to (3) of

this section to accelerate its recovery. Please be aware that operating the DHT11 sensor in the non-normal working conditions will accelerate sensor's aging process.

(2) Attention to chemical materials

Vapor from chemical materials may interfere with DHT's sensitive-elements and debase its sensitivity. A high degree of chemical contamination can permanently damage the sensor.

(3) Restoration process when (1) & (2) happen

Step one: Keep the DHT sensor at the condition of Temperature 50~60Celsius, humidity <10%RH for 2 hours;

Step two:K keep the DHT sensor at the condition of Temperature 20~30Celsius, humidity >70%RH for 5 hours.

(4) Temperature Affect

Relative humidity largely depends on temperature. Although temperature compensation technology is used to ensure accurate measurement of RH, it is still strongly advised to keep the humidity and temperature sensors working under the same temperature. DHT11 should be mounted at the place as far as possible from parts that may generate heat.

(5) Ligh t Affect

Long time exposure to strong sunlight and ultraviolet may debase DHT's performance.

(6) Connection wires

The quality of connection wires will affect the quality and distance of communication and high quality shielding-wire is recommended.

(7) Other attentions

* Welding temperature should be bellow 260Celsius and contact should take less than 10 seconds.
* Avoid using the sensor under dew condition.
* Do not use this product in safety or emergency stop devices or any other occasion that failure of DHT11 may cause personal injury.
* Storage: Keep the sensor at temperature 10-40℃, humidity <60%RH.

Disclaimer

This is a translated version of the manufacturer's data sheet. OSEPP is not responsible for the accuracy of the translated information.

DS18B20

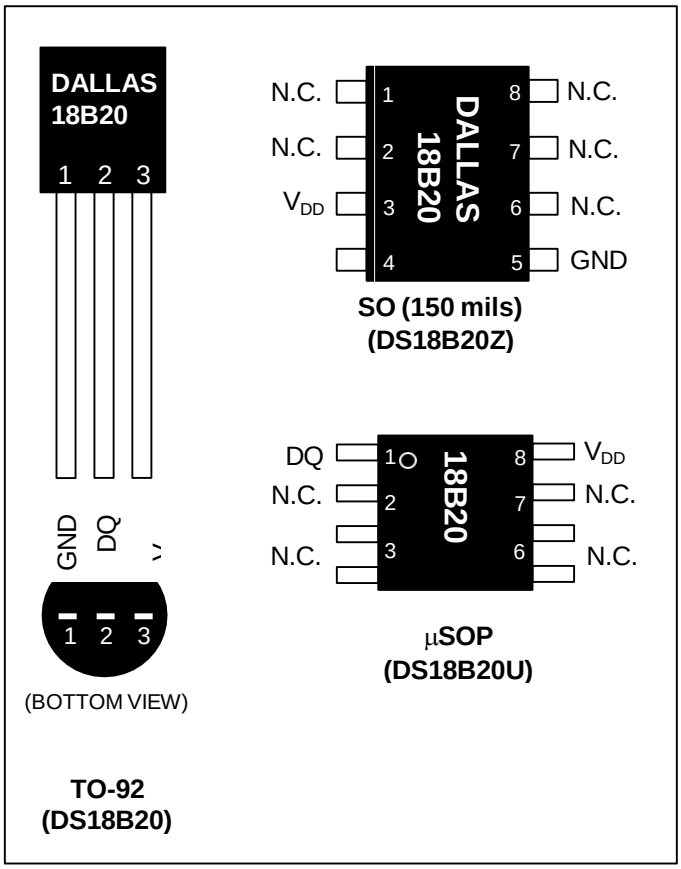
Programmable Resolution 1-Wire Digital Thermometer

www.maxim-ic.com

FEATURES

- Unique 1-Wire® Interface Requires Only One Port Pin for Communication
- Each Device has a Unique 64-Bit Serial Code Stored in an On-Board ROM
- 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
- Measures Temperatures from -55°C to +125°C (-67°F to +257°F)
- ±0.5°C Accuracy from -10°C to +85°C
- Thermometer Resolution is User Selectable from 9 to 12 Bits
- Converts Temperature to 12-Bit Digital Word in 750ms (Max)
- User-Definable Nonvolatile (NV) Alarm Settings
- Alarm Search Command Identifies and Addresses Devices Whose Temperature is Outside Programmed Limits (Temperature Alarm Condition)
- Available in 8-Pin SO (150 mils), 8-Pin µSOP, and 3-Pin TO-92 Packages
- Software Compatible with the DS1822
- Applications Include Thermostatic Controls, Industrial Systems, Consumer Products, Thermometers, or Any Thermally Sensitive System

PIN CONFIGURATIONS



DESCRIPTION

The DS18B20 digital thermometer provides 9-bit to 12-bit Celsius temperature measurements and has an alarm function with nonvolatile user-programmable upper and lower trigger points. The DS18B20 communicates over a 1-Wire bus that by definition requires only one data line (and ground) for communication with a central microprocessor. It has an operating temperature range of -55°C to +125°C and is accurate to ±0.5°C over the range of -10°C to +85°C. In addition, the DS18B20 can derive power directly from the data line ("parasite power"), eliminating the need for an external power supply.

Each DS18B20 has a unique 64-bit serial code, which allows multiple DS18B20s to function on the same 1-Wire bus. Thus, it is simple to use one microprocessor to control many DS18B20s distributed over a large area. Applications that can benefit from this feature include HVAC environmental controls, temperature monitoring systems inside buildings, equipment, or machinery, and process monitoring and control systems.

1-Wire is a registered trademark of Maxim Integrated Products, Inc.

ORDERING INFORMATION

PART	TEMP RANGE	PIN-PACKAGE	TOP MARK
DS18B20	-55°C to +125°C	3 TO-92	18B20
DS18B20+	-55°C to +125°C	3 TO-92	18B20
DS18B20/T&R	-55°C to +125°C	3 TO-92 (2000 Piece)	18B20
DS18B20+T&R	-55°C to +125°C	3 TO-92 (2000 Piece)	18B20
DS18B20-SL/T&R	-55°C to +125°C	3 TO-92 (2000 Piece)*	18B20
DS18B20-SL+T&R	-55°C to +125°C	3 TO-92 (2000 Piece)*	18B20
DS18B20U	-55°C to +125°C	8 µSOP	18B20
DS18B20U+	-55°C to +125°C	8 µSOP	18B20
DS18B20U/T&R	-55°C to +125°C	8 µSOP (3000 Piece)	18B20
DS18B20U+T&R	-55°C to +125°C	8 µSOP (3000 Piece)	18B20
DS18B20Z	-55°C to +125°C	8 SO	DS18B20
DS18B20Z+	-55°C to +125°C	8 SO	DS18B20
DS18B20Z/T&R	-55°C to +125°C	8 SO (2500 Piece)	DS18B20
DS18B20Z+T&R	-55°C to +125°C	8 SO (2500 Piece)	DS18B20

+Denotes a lead-free package. A "+" will appear on the top mark of lead-free packages.
T&R = Tape and reel.

**TO-92 packages in tape and reel can be ordered with straight or formed leads. Choose "SL" for straight leads. Bulk TO-92 orders are straight leads only.*

PIN DESCRIPTION

PIN			NAME	FUNCTION
SO	µSOP	TO-92		
1, 2, 6, 7, 8	2, 3, 5, 6, 7	—	N.C.	No Connection
3	8	3	V_{DD}	Optional V_{DD}. V_{DD} must be grounded for operation in parasite power mode.
4	1	2	DQ	Data Input/Output. Open-drain 1-Wire interface pin. Also provides power to the device when used in parasite power mode (see the *Powering the DS18B20* section.)
5	4	1	GND	Ground

OVERVIEW

Figure 1 shows a block diagram of the DS18B20, and pin descriptions are given in the *Pin Description* table. The 64-bit ROM stores the device's unique serial code. The scratchpad memory contains the 2-byte temperature register that stores the digital output from the temperature sensor. In addition, the scratchpad provides access to the 1-byte upper and lower alarm trigger registers (T_H and T_L) and the 1-byte configuration register. The configuration register allows the user to set the resolution of the temperature-to-digital conversion to 9, 10, 11, or 12 bits. The T_H, T_L, and configuration registers are nonvolatile (EEPROM), so they will retain data when the device is powered down.

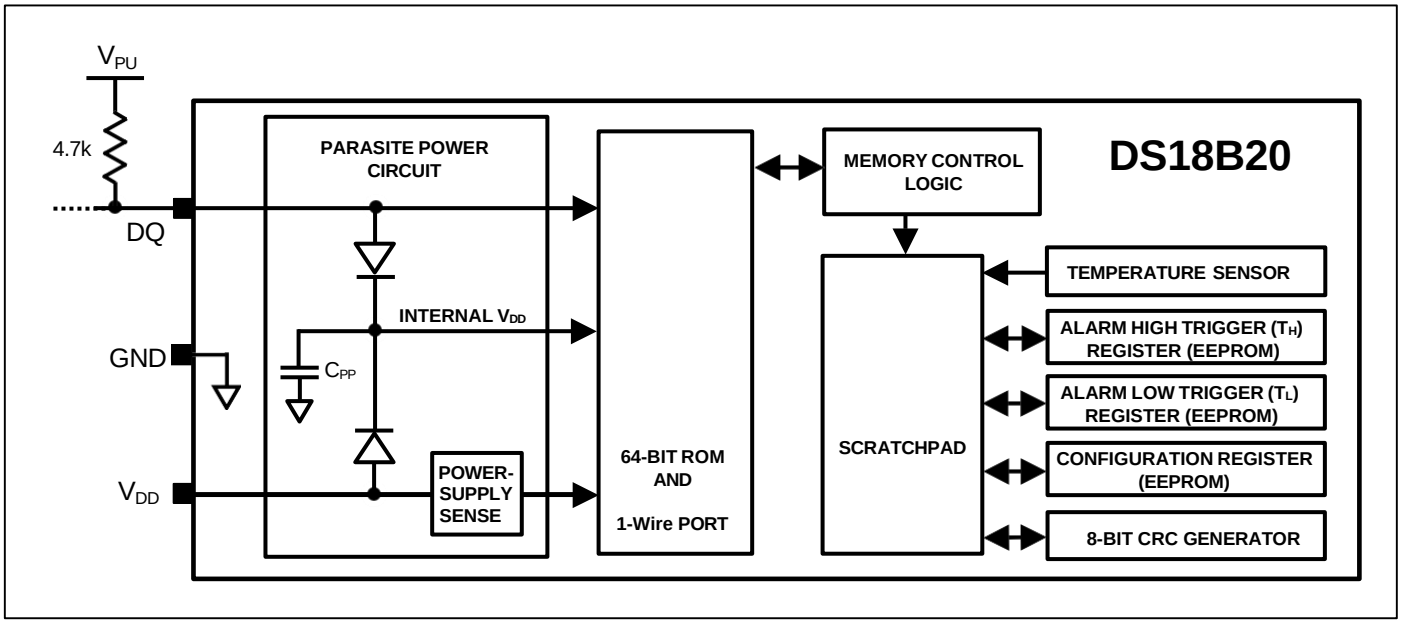
The DS18B20 uses Maxim's exclusive 1-Wire bus protocol that implements bus communication using one control signal. The control line requires a weak pullup resistor since all devices are linked to the bus via a 3-state or open-drain port (the DQ pin in the case of the DS18B20). In this bus system, the microprocessor (the master device) identifies and addresses devices on the bus using each device's unique 64-bit code.

Because each device has a unique code, the number of devices that can be addressed on one

bus is virtually unlimited. The 1-Wire bus protocol, including detailed explanations of the commands and "time slots," is covered in the *1-Wire Bus System* section.

Another feature of the DS18B20 is the ability to operate without an external power supply. Power is instead supplied through the 1-Wire pullup resistor via the DQ pin when the bus is high. The high bus signal also charges an internal capacitor (C_{PP}), which then supplies power to the device when the bus is low. This method of deriving power from the 1-Wire bus is referred to as "parasite power." As an alternative, the DS18B20 may also be powered by an external supply on V_{DD}.

Figure 1. DS18B20 Block Diagram



OPERATION—MEASURING TEMPERATURE

The core functionality of the DS18B20 is its direct-to-digital temperature sensor. The resolution of the temperature sensor is user-configurable to 9, 10, 11, or 12 bits, corresponding to increments of 0.5°C, 0.25°C, 0.125°C, and 0.0625°C, respectively. The default resolution at power-up is 12-bit. The DS18B20 powers up in a low-power idle state. To initiate a temperature measurement and A-to-D conversion, the master must issue a Convert T [44h] command. Following the conversion, the resulting thermal data is stored in the 2-byte temperature register in the scratchpad memory and the DS18B20 returns to its idle state. If the DS18B20 is powered by an external supply, the master can issue "read time slots" (see the *1-Wire Bus System* section) after the Convert T command and the DS18B20 will respond by transmitting 0 while the temperature conversion is in progress and 1 when the conversion is done. If the DS18B20 is powered with parasite power, this notification technique cannot be used since the bus must be pulled high by a strong pullup during the entire temperature conversion. The bus requirements for parasite power are explained in detail in the *Powering the DS18B20* section.

The DS18B20 output temperature data is calibrated in degrees Celsius; for Fahrenheit applications, a lookup table or conversion routine must be used. The temperature data is stored as a 16-bit sign-extended two's complement number in the temperature register (see Figure 2). The sign bits (S) indicate if the temperature is positive or negative: for positive numbers S = 0 and for negative numbers S = 1. If the DS18B20 is configured for 12-bit resolution, all bits in the temperature register will contain valid data. For 11-bit resolution, bit 0 is undefined. For 10-bit resolution, bits 1 and 0 are undefined, and for 9-bit resolution bits 2, 1, and 0 are undefined. Table 1 gives examples of digital output data and the corresponding temperature reading for 12-bit resolution conversions.

Figure 2. Temperature Register Format

	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

Table 1. Temperature/Data Relationship

TEMPERATURE (°C)	DIGITAL OUTPUT (BINARY)	DIGITAL OUTPUT (HEX)
+125	0000 0111 1101 0000	07D0h
+85*	0000 0101 0101 0000	0550h
+25.0625	0000 0001 1001 0001	0191h
+10.125	0000 0000 1010 0010	00A2h
+0.5	0000 0000 0000 1000	0008h
0	0000 0000 0000 0000	0000h
-0.5	1111 1111 1111 1000	FFF8h
-10.125	1111 1111 0101 1110	FF5Eh
-25.0625	1111 1110 0110 1111	FE6Fh
-55	1111 1100 1001 0000	FC90h

**The power-on reset value of the temperature register is +85°C.*

OPERATION—ALARM SIGNALING

After the DS18B20 performs a temperature conversion, the temperature value is compared to the user-defined two's complement alarm trigger values stored in the 1-byte T_H and T_L registers (see Figure 3). The sign bit (S) indicates if the value is positive or negative: for positive numbers S = 0 and for negative numbers S = 1. The T_H and T_L registers are nonvolatile (EEPROM) so they will retain data when the device is powered down. T_H and T_L can be accessed through bytes 2 and 3 of the scratchpad as explained in the *Memory* section.

Figure 3. T_H and T_L Register Format

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
S	2^6	2^5	2^5	2^5	2^2	2^1	2^0

Only bits 11 through 4 of the temperature register are used in the T_H and T_L comparison since T_H and T_L are 8-bit registers. If the measured temperature is lower than or equal to T_L or higher than or equal to T_H,

an alarm condition exists and an alarm flag is set inside the DS18B20. This flag is updated after every temperature measurement; therefore, if the alarm condition goes away, the flag will be turned off after the next temperature conversion.

The master device can check the alarm flag status of all DS18B20s on the bus by issuing an Alarm Search [ECh] command. Any DS18B20s with a set alarm flag will respond to the command, so the master can determine exactly which DS18B20s have experienced an alarm condition. If an alarm condition exists and the T_H or T_L settings have changed, another temperature conversion should be done to validate the alarm condition.

POWERING THE DS18B20

The DS18B20 can be powered by an external supply on the V_{DD} pin, or it can operate in "parasite power" mode, which allows the DS18B20 to function without a local external supply. Parasite power is very useful for applications that require remote temperature sensing or that are very space constrained. Figure 1 shows the DS18B20's parasite-power control circuitry, which "steals" power from the 1-Wire bus via the DQ pin when the bus is high. The stolen charge powers the DS18B20 while the bus is high, and some of the charge is stored on the parasite power capacitor (C_{PP}) to provide power when the bus is low. When the DS18B20 is used in parasite power mode, the V_{DD} pin must be connected to ground.

In parasite power mode, the 1-Wire bus and C_{PP} can provide sufficient current to the DS18B20 for most operations as long as the specified timing and voltage requirements are met (see the *DC Electrical Characteristics* and *AC Electrical Characteristics*). However, when the DS18B20 is performing temperature conversions or copying data from the scratchpad memory to EEPROM, the operating current can be as high as 1.5mA. This current can cause an unacceptable voltage drop across the weak 1-Wire pullup resistor and is more current than can be supplied by C_{PP}. To assure that the DS18B20 has sufficient supply current, it is necessary to provide a strong pullup on the 1-Wire bus whenever temperature conversions are taking place or data is being copied from the scratchpad to EEPROM. This can be accomplished by using a MOSFET to pull the bus directly to the rail as shown in Figure 4. The 1-Wire bus must be switched to the strong pullup within 10µs (max) after a Convert T [44h] or Copy Scratchpad [48h] command is issued, and the bus must be held high by the pullup for the duration of the conversion (t_{CONV}) or data transfer (t_{WR} = 10ms). No other activity can take place on the 1-Wire bus while the pullup is enabled.

The DS18B20 can also be powered by the conventional method of connecting an external power supply to the V_{DD} pin, as shown in Figure 5. The advantage of this method is that the MOSFET pullup is not required, and the 1-Wire bus is free to carry other traffic during the temperature conversion time.

The use of parasite power is not recommended for temperatures above +100°C since the DS18B20 may not be able to sustain communications due to the higher leakage currents that can exist at these temperatures. For applications in which such temperatures are likely, it is strongly recommended that the DS18B20 be powered by an external power supply.

In some situations the bus master may not know whether the DS18B20s on the bus are parasite powered or powered by external supplies. The master needs this information to determine if the strong bus pullup should be used during temperature conversions. To get this information, the master can issue a Skip ROM [CCh] command followed by a Read Power Supply [B4h] command followed by a "read time slot". During the read time slot, parasite powered DS18B20s will pull the bus low, and externally powered DS18B20s will let the bus remain high. If the bus is pulled low, the master knows that it must supply the strong pullup on the 1-Wire bus during temperature conversions.

Figure 4. Supplying the Parasite-Powered DS18B20 During Temperature Conversions

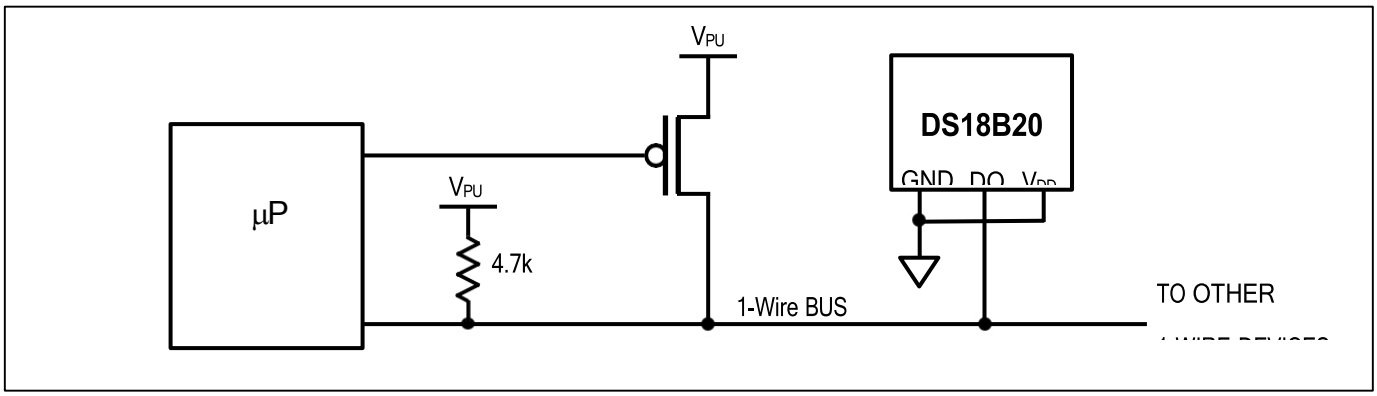
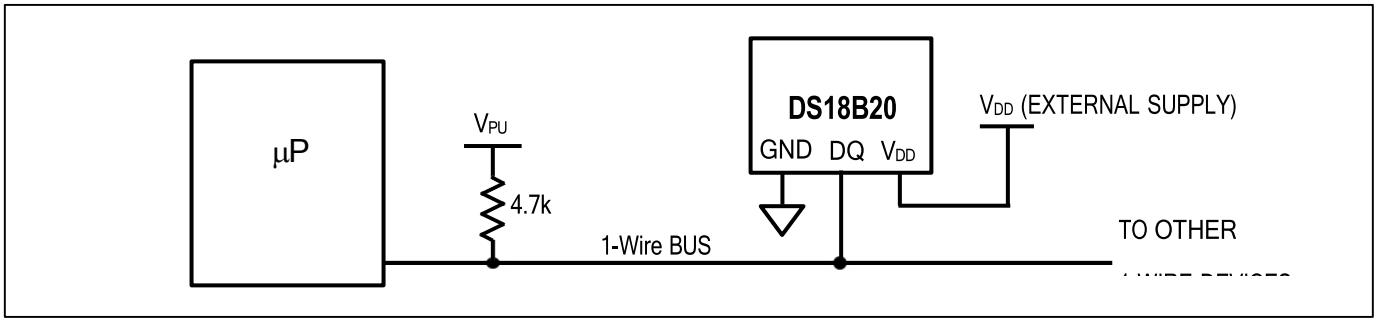


Figure 5. Powering the DS18B20 with an External Supply



64-BIT LASERED ROM CODE

Each DS18B20 contains a unique 64–bit code (see Figure 6) stored in ROM. The least significant 8 bits of the ROM code contain the DS18B20's 1-Wire family code: 28h. The next 48 bits contain a unique serial number. The most significant 8 bits contain a cyclic redundancy check (CRC) byte that is calculated from the first 56 bits of the ROM code. A detailed explanation of the CRC bits is provided in the *CRC Generation* section. The 64-bit ROM code and associated ROM function control logic allow the DS18B20 to operate as a 1-Wire device using the protocol detailed in the *1-Wire Bus System* section.

Figure 6. 64-Bit Lasered ROM Code

8-BIT CRC		48-BIT SERIAL NUMBER		8-BIT FAMILY CODE (28h)	
MSB	LSB	MSB	LSB	MSB	LSB

MEMORY

The DS18B20's memory is organized as shown in Figure 7. The memory consists of an SRAM scratchpad with nonvolatile EEPROM storage for the high and low alarm trigger registers (T_H and T_L) and configuration register. Note that if the DS18B20 alarm function is not used, the T_H and T_L registers can serve as general-purpose memory. All memory commands are described in detail in the *DS18B20 Function Commands* section.

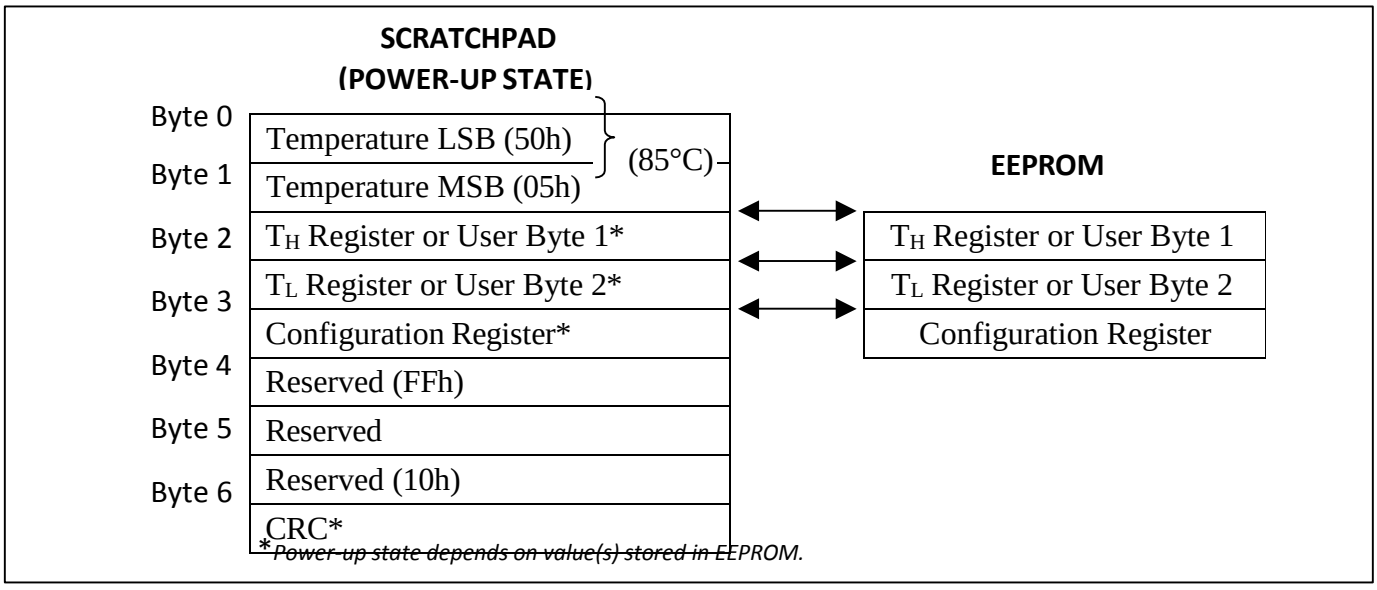
Byte 0 and byte 1 of the scratchpad contain the LSB and the MSB of the temperature register, respectively. These bytes are read-only. Bytes 2 and 3 provide access to T_H and T_L registers. Byte 4 contains the configuration register data, which is explained in detail in the *Configuration Register* section. Bytes 5, 6, and 7 are reserved for internal use by the device and cannot be overwritten.

Byte 8 of the scratchpad is read-only and contains the CRC code for bytes 0 through 7 of the scratchpad. The DS18B20 generates this CRC using the method described in the *CRC Generation* section.

Data is written to bytes 2, 3, and 4 of the scratchpad using the Write Scratchpad [4Eh] command; the data must be transmitted to the DS18B20 starting with the least significant bit of byte 2. To verify data integrity, the scratchpad can be read (using the Read Scratchpad [BEh] command) after the data is written. When reading the scratchpad, data is transferred over the 1-Wire bus starting with the least significant bit of byte 0. To transfer the T_H, T_L and configuration data from the scratchpad to EEPROM, the master must issue the Copy Scratchpad [48h] command.

Data in the EEPROM registers is retained when the device is powered down; at power-up the EEPROM data is reloaded into the corresponding scratchpad locations. Data can also be reloaded from EEPROM to the scratchpad at any time using the Recall E^2 [B8h] command. The master can issue read time slots following the Recall E^2 command and the DS18B20 will indicate the status of the recall by transmitting 0 while the recall is in progress and 1 when the recall is done.

Figure 7. DS18B20 Memory Map



CONFIGURATION REGISTER

Byte 4 of the scratchpad memory contains the configuration register, which is organized as illustrated in Figure 8**.** The user can set the conversion resolution of the DS18B20 using the R0 and R1 bits in this register as shown in Table 2. The power-up default of these bits is R0 = 1 and R1 = 1 (12-bit resolution). Note that there is a direct tradeoff between resolution and conversion time. Bit 7 and bits 0 to 4 in the configuration register are reserved for internal use by the device and cannot be overwritten.

Figure 8. Configuration Register

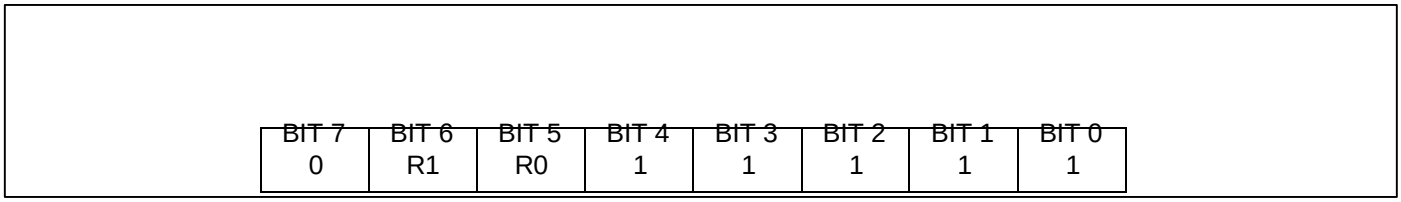


Table 2. Thermometer Resolution Configuration

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})

CRC GENERATION

CRC bytes are provided as part of the DS18B20's 64-bit ROM code and in the 9th byte of the scratchpad memory. The ROM code CRC is calculated from the first 56 bits of the ROM code and is contained in the most significant byte of the ROM. The scratchpad CRC is calculated from the data stored in the scratchpad, and therefore it changes when the data in the scratchpad changes. The CRCs provide the bus master with a method of data validation when data is read from the DS18B20. To verify that data has been read correctly, the bus master must re-calculate the CRC from the received data and then compare this value to either the ROM code CRC (for ROM reads) or to the scratchpad CRC (for scratchpad reads). If the calculated CRC matches the read CRC, the data has been received error free. The comparison of CRC values and the decision to continue with an operation are determined entirely by the bus master. There is no circuitry inside the DS18B20 that prevents a command sequence from proceeding if the DS18B20 CRC (ROM or scratchpad) does not match the value generated by the bus master.

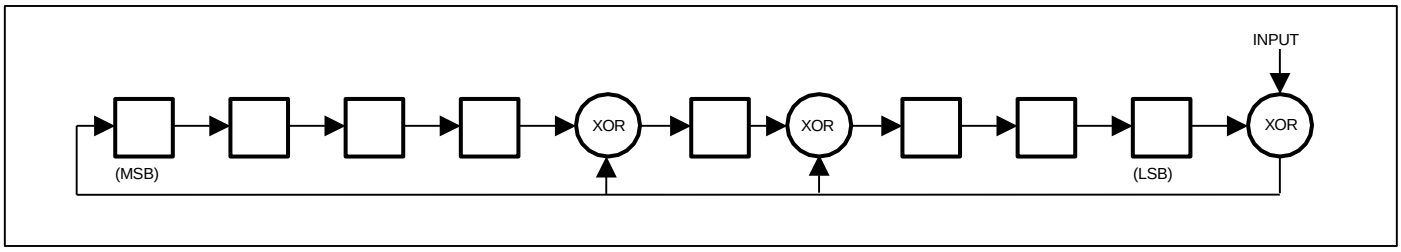
The equivalent polynomial function of the CRC (ROM or scratchpad) is:

$$CRC = X^8 + X^5 + X^4 + 1$$

The bus master can re-calculate the CRC and compare it to the CRC values from the DS18B20 using the polynomial generator shown in Figure 9. This circuit consists of a shift register and XOR gates, and the shift register bits are initialized to 0. Starting with the least significant bit of the ROM code or the least significant bit of byte 0 in the scratchpad, one bit at a time should shifted into the shift register. After shifting in the 56th bit from the ROM or the most significant bit of byte 7 from the scratchpad, the polynomial generator will contain the re-calculated CRC. Next, the 8-bit ROM code or scratchpad CRC from the DS18B20 must be shifted into the circuit. At this point, if the re-calculated CRC was correct, the shift register will contain all 0s. Additional information about the Maxim 1-Wire cyclic redundancy check

is available in *Application Note 27: Understanding and Using Cyclic Redundancy Checks with Maxim iButton Products*.

Figure 9. CRC Generator



1-WIRE BUS SYSTEM

The 1-Wire bus system uses a single bus master to control one or more slave devices. The DS18B20 is always a slave. When there is only one slave on the bus, the system is referred to as a "single-drop" system; the system is "multidrop" if there are multiple slaves on the bus.

All data and commands are transmitted least significant bit first over the 1-Wire bus.

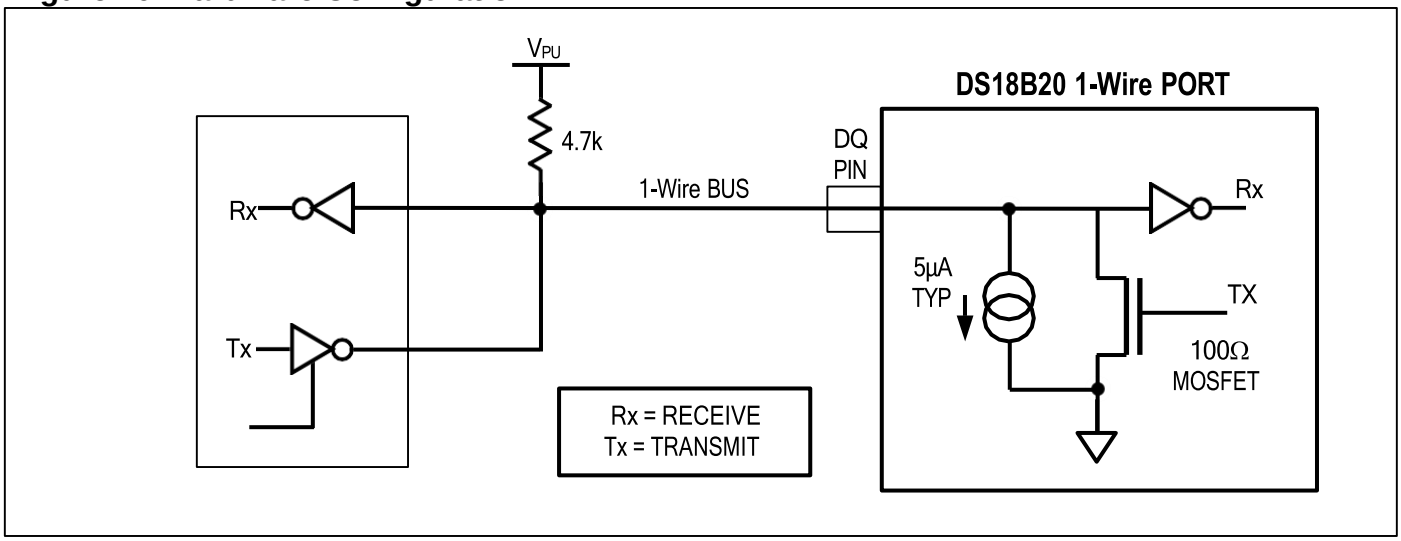
The following discussion of the 1-Wire bus system is broken down into three topics: hardware configuration, transaction sequence, and 1-Wire signaling (signal types and timing).

HARDWARE CONFIGURATION

The 1-Wire bus has by definition only a single data line. Each device (master or slave) interfaces to the data line via an open-drain or 3-state port. This allows each device to "release" the data line when the device is not transmitting data so the bus is available for use by another device. The 1-Wire port of the DS18B20 (the DQ pin) is open drain with an internal circuit equivalent to that shown in Figure 10.

The 1-Wire bus requires an external pullup resistor of approximately 5kΩ; thus, the idle state for the 1-Wire bus is high. If for any reason a transaction needs to be suspended, the bus MUST be left in the idle state if the transaction is to resume. Infinite recovery time can occur between bits so long as the 1-Wire bus is in the inactive (high) state during the recovery period. If the bus is held low for more than 480µs, all components on the bus will be reset.

Figure 10. Hardware Configuration



TRANSACTION SEQUENCE

The transaction sequence for accessing the DS18B20 is as follows:

Step 1. Initialization

Step 2. ROM Command (followed by any required data exchange)

Step 3. DS18B20 Function Command (followed by any required data exchange)

It is very important to follow this sequence every time the DS18B20 is accessed, as the DS18B20 will not respond if any steps in the sequence are missing or out of order. Exceptions to this rule are the Search ROM [F0h] and Alarm Search [ECh] commands. After issuing either of these ROM commands, the master must return to Step 1 in the sequence.

INITIALIZATION

All transactions on the 1-Wire bus begin with an initialization sequence. The initialization sequence consists of a reset pulse transmitted by the bus master followed by presence pulse(s) transmitted by the slave(s). The presence pulse lets the bus master know that slave devices (such as the DS18B20) are on the bus and are ready to operate. Timing for the reset and presence pulses is detailed in the *1-Wire Signaling* section.

ROM COMMANDS

After the bus master has detected a presence pulse, it can issue a ROM command. These commands operate on the unique 64-bit ROM codes of each slave device and allow the master to single out a specific device if many are present on the 1-Wire bus. These commands also allow the master to determine how many and what types of devices are present on the bus or if any device has experienced an alarm condition. There are five ROM commands, and each command is 8 bits long. The master device must issue an appropriate ROM command before issuing a DS18B20 function command. A flowchart for operation of the ROM commands is shown in Figure 11.

SEARCH ROM [F0h]

When a system is initially powered up, the master must identify the ROM codes of all slave devices on the bus, which allows the master to determine the number of slaves and their device types. The master learns the ROM codes through a process of elimination that requires the master to perform a Search ROM cycle (i.e., Search ROM command followed by data exchange) as many times as necessary to identify all of the slave devices. If there is only one slave on the bus, the simpler Read ROM command (see below) can be used in place of the Search ROM process. For a detailed explanation of the Search ROM procedure, refer to the *iButton® Book of Standards* at www.maxim-ic.com/ibuttonbook. After every Search ROM cycle, the bus master must return to Step 1 (Initialization) in the transaction sequence.

READ ROM [33h]

This command can only be used when there is one slave on the bus. It allows the bus master to read the slave's 64-bit ROM code without using the Search ROM procedure. If this command is used when there is more than one slave present on the bus, a data collision will occur when all the slaves attempt to respond at the same time.

MATCH ROM [55h]

The match ROM command followed by a 64-bit ROM code sequence allows the bus master to address a specific slave device on a multidrop or single-drop bus. Only the slave that exactly matches the 64-bit ROM code sequence will respond to the function command issued by the master; all other slaves on the bus will wait for a reset pulse.

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SKIP ROM [CCh]

The master can use this command to address all devices on the bus simultaneously without sending out any ROM code information. For example, the master can make all DS18B20s on the bus perform simultaneous temperature conversions by issuing a Skip ROM command followed by a Convert T [44h] command.

Note that the Read Scratchpad [BEh] command can follow the Skip ROM command only if there is a single slave device on the bus. In this case, time is saved by allowing the master to read from the slave without sending the device's 64-bit ROM code. A Skip ROM command followed by a Read Scratchpad command will cause a data collision on the bus if there is more than one slave since multiple devices will attempt to transmit data simultaneously.

ALARM SEARCH [ECh]

The operation of this command is identical to the operation of the Search ROM command except that only slaves with a set alarm flag will respond. This command allows the master device to determine if any DS18B20s experienced an alarm condition during the most recent temperature conversion. After every Alarm Search cycle (i.e., Alarm Search command followed by data exchange), the bus master must return to Step 1 (Initialization) in the transaction sequence. See the *Operation—Alarm Signaling* section for an explanation of alarm flag operation.

DS18B20 FUNCTION COMMANDS

After the bus master has used a ROM command to address the DS18B20 with which it wishes to communicate, the master can issue one of the DS18B20 function commands. These commands allow the master to write to and read from the DS18B20's scratchpad memory, initiate temperature conversions and determine the power supply mode. The DS18B20 function commands, which are described below, are summarized in Table 3 and illustrated by the flowchart in Figure 12.

CONVERT T [44h]

This command initiates a single temperature conversion. Following the conversion, the resulting thermal data is stored in the 2-byte temperature register in the scratchpad memory and the DS18B20 returns to its low-power idle state. If the device is being used in parasite power mode, within 10μs (max) after this command is issued the master must enable a strong pullup on the 1-Wire bus for the duration of the conversion (t_{CONV}) as described in the *Powering the DS18B20* section. If the DS18B20 is powered by an external supply, the master can issue read time slots after the Convert T command and the DS18B20 will respond by transmitting a 0 while the temperature conversion is in progress and a 1 when the conversion is done. In parasite power mode this notification technique cannot be used since the bus is pulled high by the strong pullup during the conversion.

WRITE SCRATCHPAD [4Eh]

This command allows the master to write 3 bytes of data to the DS18B20's scratchpad. The first data byte is written into the T_H register (byte 2 of the scratchpad), the second byte is written into the T_L register (byte 3), and the third byte is written into the configuration register (byte 4). Data must be transmitted least significant bit first. All three bytes MUST be written before the master issues a reset, or the data may be corrupted.

READ SCRATCHPAD [BEh]

This command allows the master to read the contents of the scratchpad. The data transfer starts with the least significant bit of byte 0 and continues through the scratchpad until the 9th byte (byte 8 – CRC) is read. The master may issue a reset to terminate reading at any time if only part of the scratchpad data is needed.

COPY SCRATCHPAD [48h]

This command copies the contents of the scratchpad T_H, T_L and configuration registers (bytes 2, 3 and 4) to EEPROM. If the device is being used in parasite power mode, within 10μs (max) after this command is issued the master must enable a strong pullup on the 1-Wire bus for at least 10ms as described in the *Powering the DS18B20* section.

RECALL E^2 [B8h]

This command recalls the alarm trigger values (T_H and T_L) and configuration data from EEPROM and places the data in bytes 2, 3, and 4, respectively, in the scratchpad memory. The master device can issue read time slots following the Recall E^2 command and the DS18B20 will indicate the status of the recall by transmitting 0 while the recall is in progress and 1 when the recall is done. The recall operation happens automatically at power-up, so valid data is available in the scratchpad as soon as power is applied to the device.

READ POWER SUPPLY [B4h]

The master device issues this command followed by a read time slot to determine if any DS18B20s on the bus are using parasite power. During the read time slot, parasite powered DS18B20s will pull the bus low, and externally powered DS18B20s will let the bus remain high. See the *Powering the DS18B20* section for usage information for this command.

Table 3. DS18B20 Function Command Set

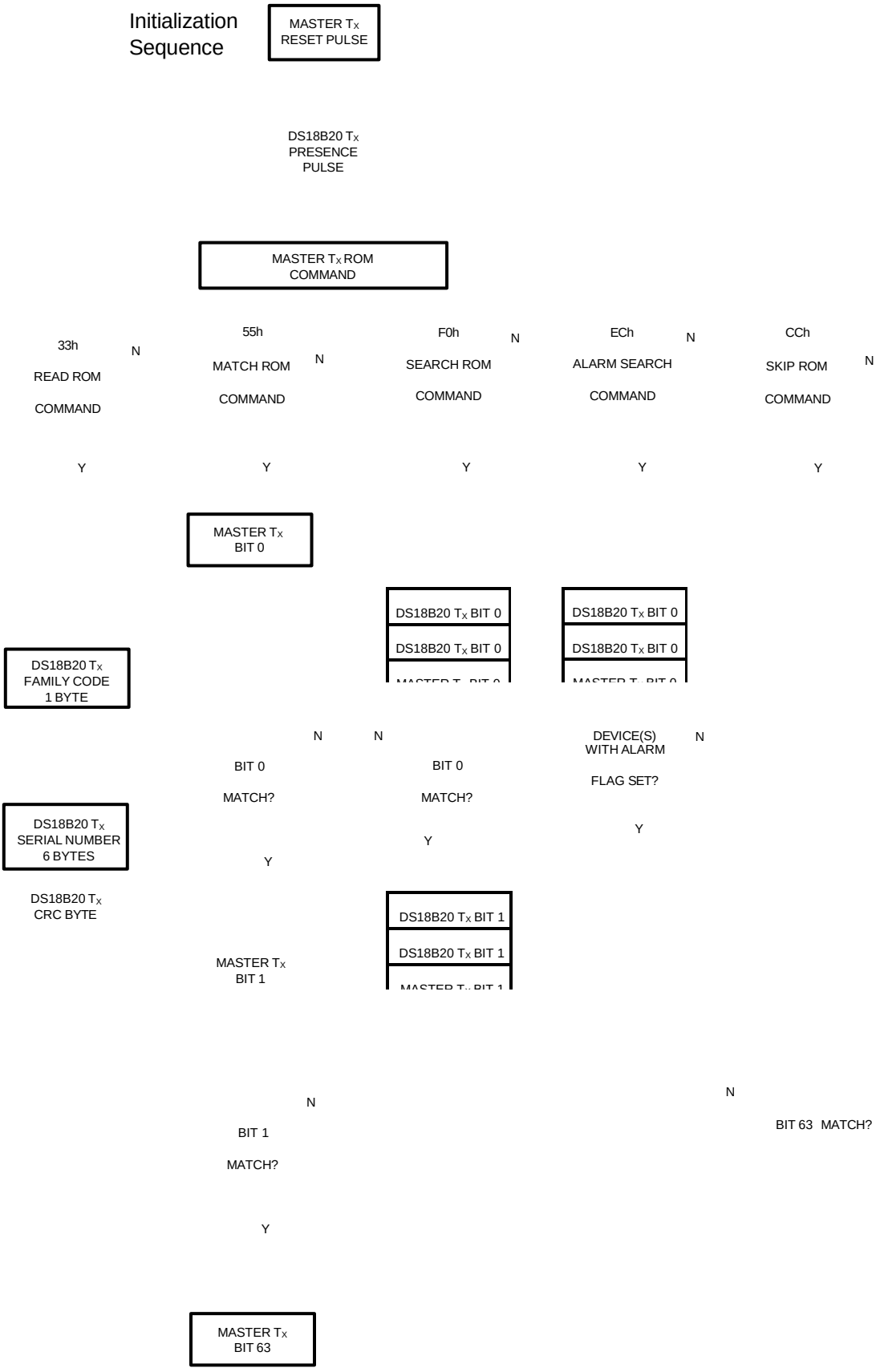
COMMAND	DESCRIPTION	PROTOCOL	1-Wire BUS ACTIVITYAFTER COMMAND IS ISSUED	NOTES
TEMPERATURE CONVERSION COMMANDS				
Convert T	Initiates temperature conversion.	44h	DS18B20 transmits conversion status to master (not applicable for parasite-powered DS18B20s).	1
MEMORY COMMANDS				
Read Scratchpad	Reads the entire scratchpad including the CRC byte.	BEh	DS18B20 transmits up to 9 data bytes to master.	2
Write Scratchpad	Writes data into scratchpad bytes 2, 3, and 4 (T_H, T_L, and configuration registers).	4Eh	Master transmits 3 data bytes to DS18B20.	3
Copy Scratchpad	Copies T_H, T_L, and configuration register data from the scratchpad to EEPROM.	48h	None	1
Recall E^2	Recalls T_H, T_L, and configuration register data from EEPROM to the scratchpad.	B8h	DS18B20 transmits recall status to master.	
Read Power Supply	Signals DS18B20 power supply mode to the master.	B4h	DS18B20 transmits supply status to master.	

Note 1: For parasite-powered DS18B20s, the master must enable a strong pullup on the 1-Wire bus during temperature conversions and copies from the scratchpad to EEPROM. No other bus activity may take place during this time.

Note 2: The master can interrupt the transmission of data at any time by issuing a reset.

Note 3: All three bytes must be written before a reset is issued.

Figure 11. ROM Commands Flowchart



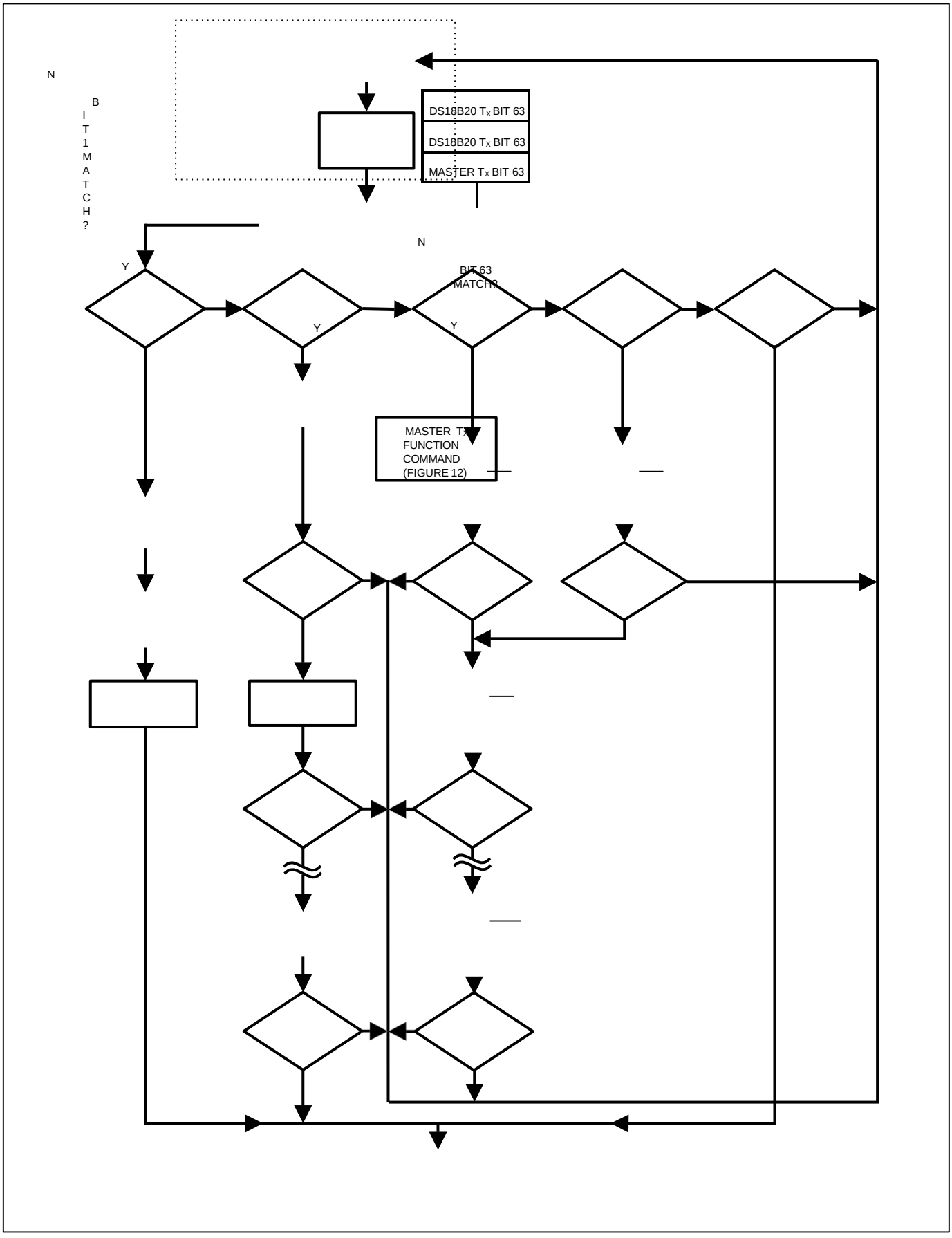
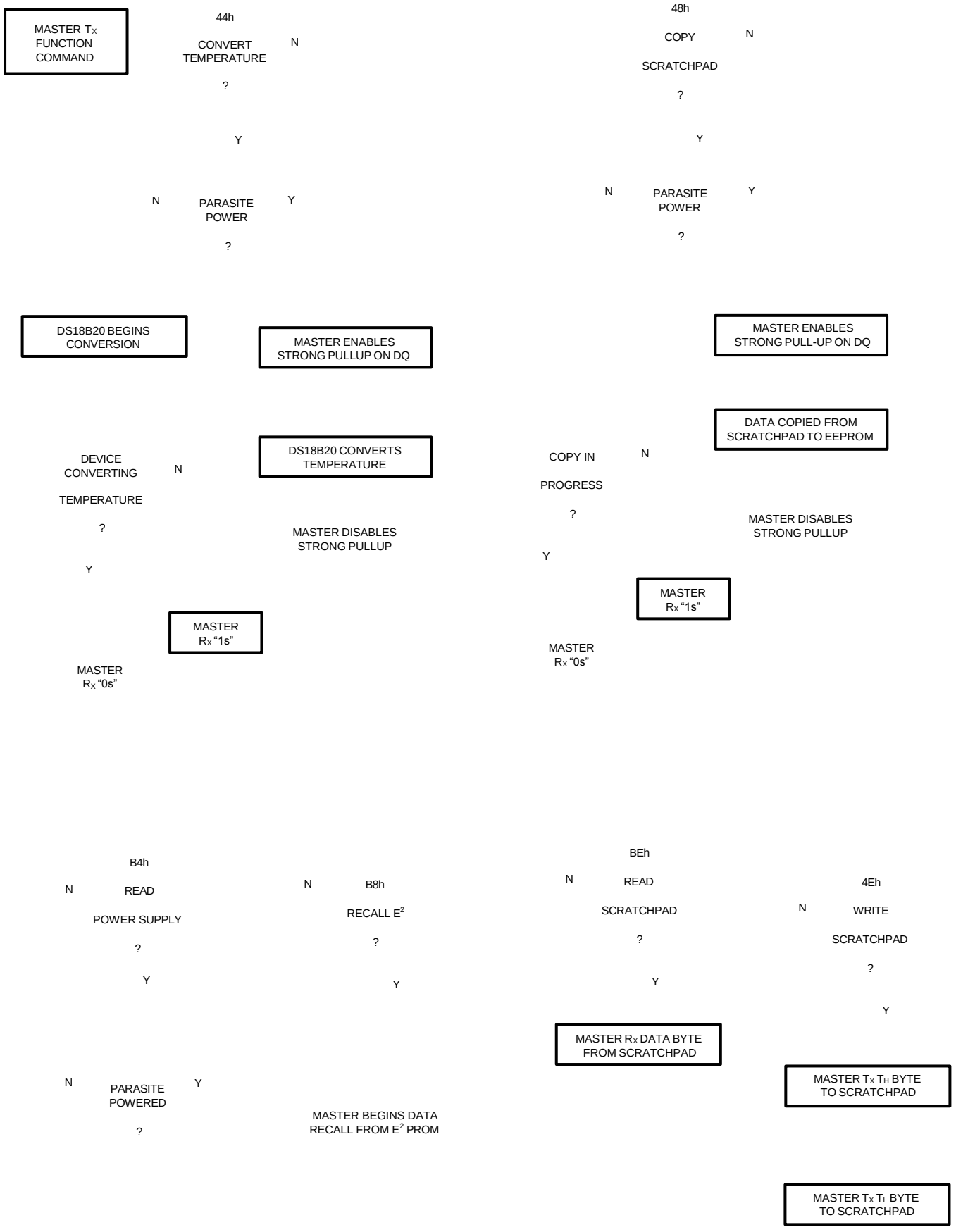
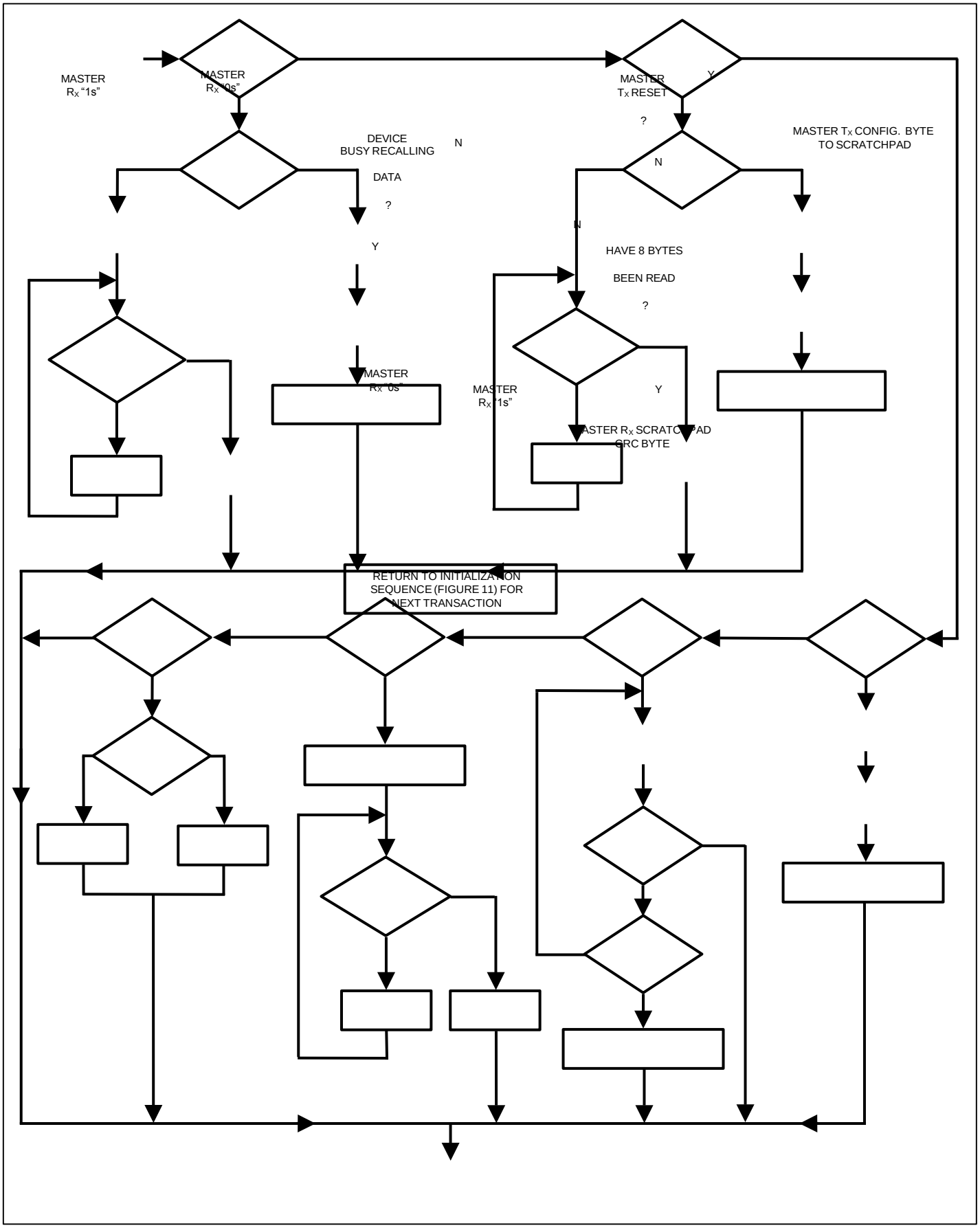

N
B
I
T
1
M
A
T
C
H
?
DS18B20 TX BIT 63
DS18B20 TX BIT 63
MASTER TX BIT 63
N
Y
BIT 63
MATCH?
Y
Y
MASTER TX
FUNCTION
COMMAND
(FIGURE 12)

Figure 12. DS18B20 Function Commands Flowchart




MASTER
RX "1s"
MASTER
RX "0s"
MASTER
TX RESET
Y
?
DEVICE
BUSY RECALLING
N
DATA
?
N
MASTER TX CONFIG. BYTE
TO SCRATCHPAD
N
HAVE 8 BYTES
BEEN READ
?
Y
MASTER
RX "0s"
MASTER
RX "1s"
Y
MASTER RX SCRATCHPAD
CRC BYTE
RETURN TO INITIALIZATION
SEQUENCE (FIGURE 11) FOR
NEXT TRANSACTION

1-WIRE SIGNALING

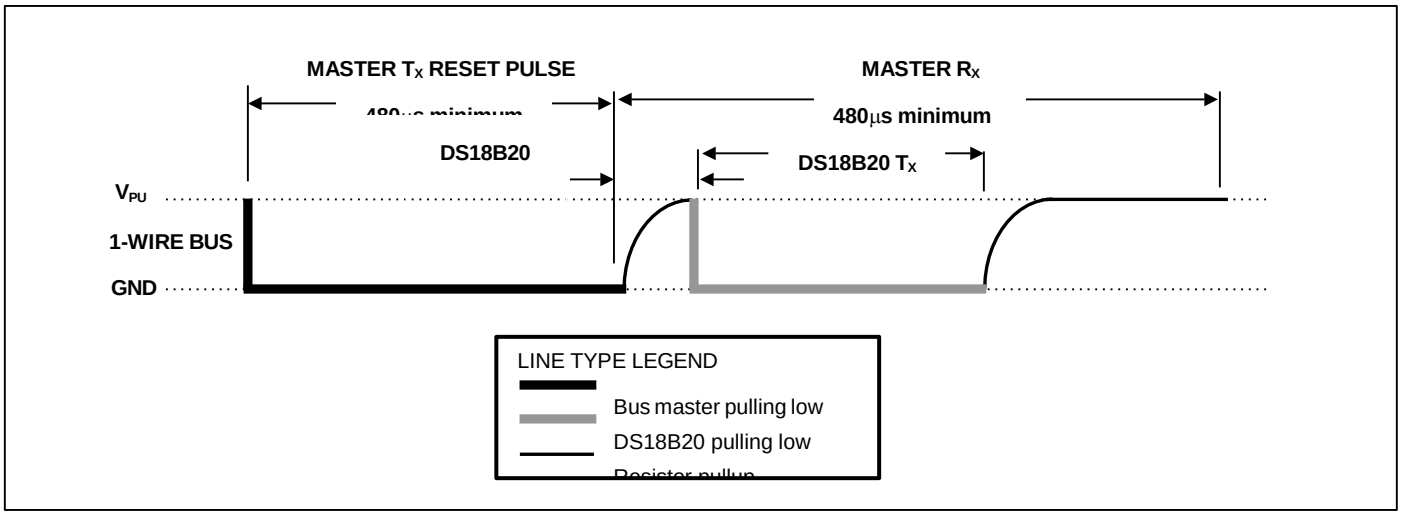
The DS18B20 uses a strict 1-Wire communication protocol to ensure data integrity. Several signal types are defined by this protocol: reset pulse, presence pulse, write 0, write 1, read 0, and read 1. The bus master initiates all these signals, with the exception of the presence pulse.

INITIALIZATION PROCEDURE—RESET AND PRESENCE PULSES

All communication with the DS18B20 begins with an initialization sequence that consists of a reset pulse from the master followed by a presence pulse from the DS18B20. This is illustrated in Figure 13. When the DS18B20 sends the presence pulse in response to the reset, it is indicating to the master that it is on the bus and ready to operate.

During the initialization sequence the bus master transmits (T_X) the reset pulse by pulling the 1-Wire bus low for a minimum of 480µs. The bus master then releases the bus and goes into receive mode (R_X). When the bus is released, the 5kΩ pullup resistor pulls the 1-Wire bus high. When the DS18B20 detects this rising edge, it waits 15µs to 60µs and then transmits a presence pulse by pulling the 1-Wire bus low for 60µs to 240µs.

Figure 13. Initialization Timing



READ/WRITE TIME SLOTS

The bus master writes data to the DS18B20 during write time slots and reads data from the DS18B20 during read time slots. One bit of data is transmitted over the 1-Wire bus per time slot.

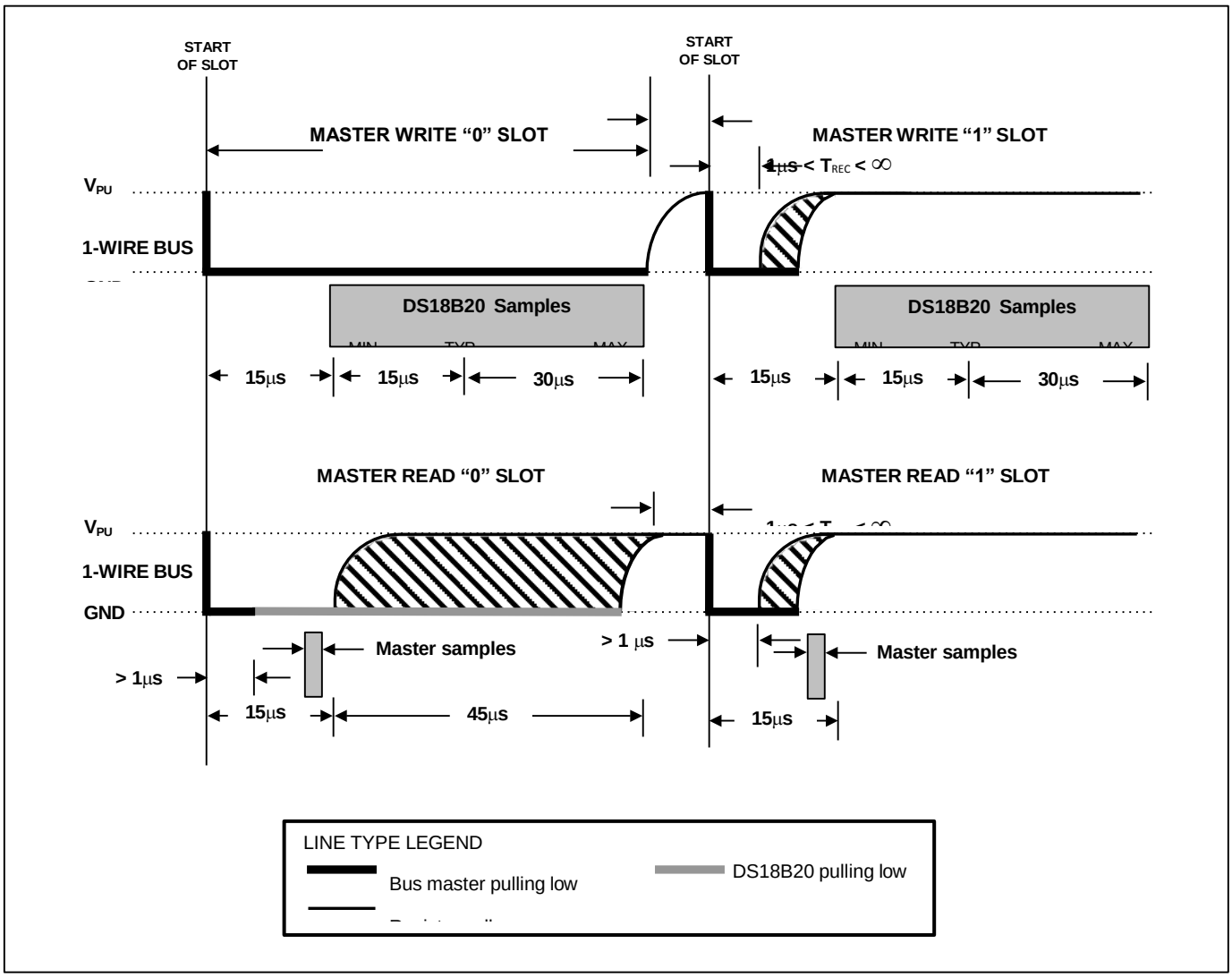
WRITE TIME SLOTS

There are two types of write time slots: "Write 1" time slots and "Write 0" time slots. The bus master uses a Write 1 time slot to write a logic 1 to the DS18B20 and a Write 0 time slot to write a logic 0 to the DS18B20. All write time slots must be a minimum of 60µs in duration with a minimum of a 1µs recovery time between individual write slots. Both types of write time slots are initiated by the master pulling the 1-Wire bus low (see Figure 14).

To generate a Write 1 time slot, after pulling the 1-Wire bus low, the bus master must release the 1-Wire bus within 15µs. When the bus is released, the 5kΩ pullup resistor will pull the bus high. To generate a Write 0 time slot, after pulling the 1-Wire bus low, the bus master must continue to hold the bus low for the duration of the time slot (at least 60µs).

The DS18B20 samples the 1-Wire bus during a window that lasts from 15µs to 60µs after the master initiates the write time slot. If the bus is high during the sampling window, a 1 is written to the DS18B20. If the line is low, a 0 is written to the DS18B20.

Figure 14. Read/Write Time Slot Timing Diagram



READ TIME SLOTS

The DS18B20 can only transmit data to the master when the master issues read time slots. Therefore, the master must generate read time slots immediately after issuing a Read Scratchpad [BEh] or Read Power Supply [B4h] command, so that the DS18B20 can provide the requested data. In addition, the master can generate read time slots after issuing Convert T [44h] or Recall E^2 [B8h] commands to find out the status of the operation as explained in the *DS18B20 Function Commands* section.

All read time slots must be a minimum of 60µs in duration with a minimum of a 1µs recovery time between slots. A read time slot is initiated by the master device pulling the 1-Wire bus low for a minimum of 1µs and then releasing the bus (see Figure 14). After the master initiates the read time slot, the DS18B20 will begin transmitting a 1 or 0 on bus. The DS18B20 transmits a 1 by leaving the bus high and transmits a 0 by pulling the bus low. When transmitting a 0, the DS18B20 will release the bus by the end of the time slot, and the bus will be pulled back to its high idle state by the pullup resister. Output

data from the DS18B20 is valid for 15µs after the falling edge that initiated the read time slot. Therefore, the master must release the bus and then sample the bus state within 15µs from the start of the slot.

Figure 15 illustrates that the sum of T_{INIT}, T_{RC}, and T_{SAMPLE} must be less than 15µs for a read time slot. Figure 16 shows that system timing margin is maximized by keeping T_{INIT} and T_{RC} as short as possible and by locating the master sample time during read time slots towards the end of the 15µs period.

Figure 15. Detailed Master Read 1 Timing

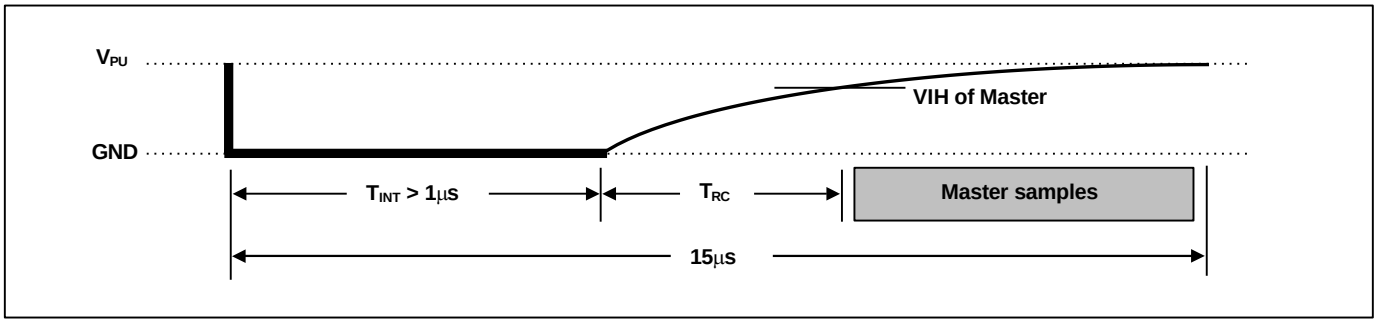
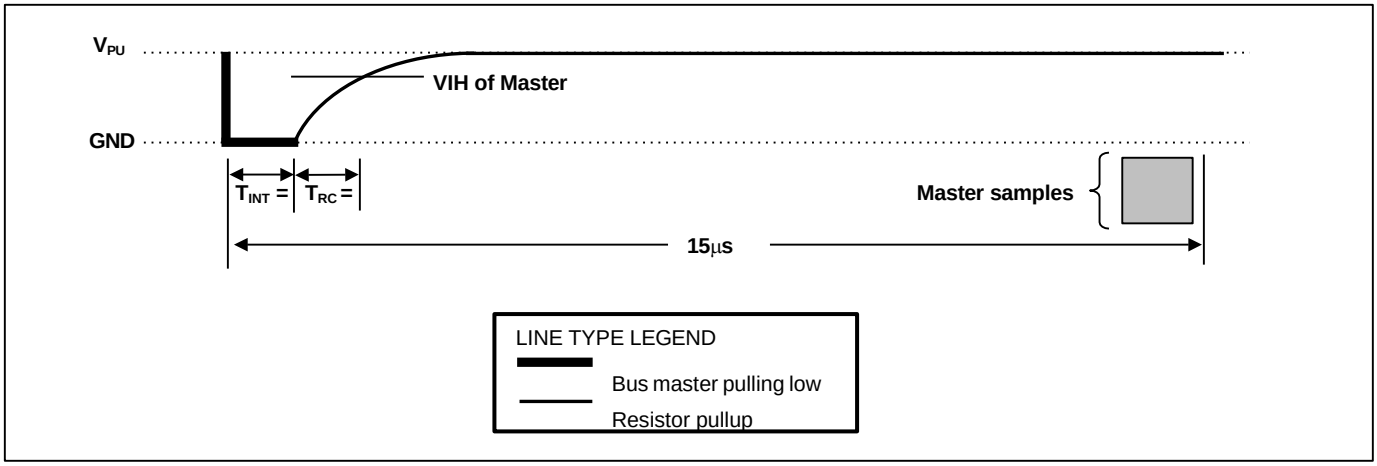


Figure 16. Recommended Master Read 1 Timing



RELATED APPLICATION NOTES

The following application notes can be applied to the DS18B20 and are available on our website at www.maxim-ic.com.

Application Note 27: Understanding and Using Cyclic Redundancy Checks with Maxim iButton Products
Application Note 122: Using Dallas' 1-Wire ICs in 1-Cell Li-Ion Battery Packs with Low-Side N-Channel Safety FETs Master

Application Note 126: 1-Wire Communication Through Software

Application Note 162: Interfacing the DS18x20/DS1822 1-Wire Temperature Sensor in a Microcontroller Environment

Application Note 208: Curve Fitting the Error of a Bandgap-Based Digital Temperature Sensor
Application Note 2420: 1-Wire Communication with a Microchip PICmicro Microcontroller
Application Note 3754: Single-Wire Serial Bus Carries Isolated Power and Data

Sample 1-Wire subroutines that can be used in conjunction with *Application Note 74: Reading and Writing iButtons via Serial Interfaces* can be downloaded from the Maxim website.

DS18B20 OPERATION EXAMPLE 1

In this example there are multiple DS18B20s on the bus and they are using parasite power. The bus master initiates a temperature conversion in a specific DS18B20 and then reads its scratchpad and recalculates the CRC to verify the data.

MASTER MODE	DATA (LSB FIRST)	COMMENTS
Tx	Reset	Master issues reset pulse.
Rx	Presence	DS18B20s respond with presence pulse.
Tx	55h	Master issues Match ROM command.
Tx	64-bit ROM code	Master sends DS18B20 ROM code.
Tx	44h	Master issues Convert T command.
Tx	DQ line held high by strong pullup	Master applies strong pullup to DQ for the duration of the conversion (t_{CONV}).
Tx	Reset	Master issues reset pulse.
Rx	Presence	DS18B20s respond with presence pulse.
Tx	55h	Master issues Match ROM command.
Tx	64-bit ROM code	Master sends DS18B20 ROM code.
Tx	BEh	Master issues Read Scratchpad command.
Rx	9 data bytes	Master reads entire scratchpad including CRC. The master then recalculates the CRC of the first eight data bytes from the scratchpad and compares the calculated CRC with the read CRC (byte 9). If they match, the master continues; if not, the read operation is repeated.

DS18B20 OPERATION EXAMPLE 2

In this example there is only one DS18B20 on the bus and it is using parasite power. The master writes to the T_H, T_L, and configuration registers in the DS18B20 scratchpad and then reads the scratchpad and recalculates the CRC to verify the data. The master then copies the scratchpad contents to EEPROM.

MASTER MODE	DATA (LSB FIRST)	COMMENTS
Tx	Reset	Master issues reset pulse.
Rx	Presence	DS18B20 responds with presence pulse.
Tx	CCh	Master issues Skip ROM command.
Tx	4Eh	Master issues Write Scratchpad command.
Tx	3 data bytes	Master sends three data bytes to scratchpad (T_H, T_L, and config).
Tx	Reset	Master issues reset pulse.
Rx	Presence	DS18B20 responds with presence pulse.
Tx	CCh	Master issues Skip ROM command.
Tx	BEh	Master issues Read Scratchpad command.
Rx	9 data bytes	Master reads entire scratchpad including CRC. The master then recalculates the CRC of the first eight data bytes from the scratchpad and compares the calculated CRC with the read CRC (byte 9). If they match, the master continues; if not, the read operation is repeated.
Tx	Reset	Master issues reset pulse.
Rx	Presence	DS18B20 responds with presence pulse.
Tx	CCh	Master issues Skip ROM command.
Tx	48h	Master issues Copy Scratchpad command.
Tx	DQ line held high by strong pullup	Master applies strong pullup to DQ for at least 10ms while copy operation is in progress.

ABSOLUTE MAXIMUM RATINGS

Voltage Range on Any Pin Relative to Ground..... V to +6.0V
Operating Temperature Range.....-55°C to +125°C
Storage Temperature Range.....-55°C to +125°C
Solder Temperature.....Refer to the IPC/JEDEC J-STD-020 Specification.

These are stress ratings only and functional operation of the device at these or any other conditions above those indicated in the operation sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods of time may affect reliability.

DC ELECTRICAL CHARACTERISTICS (-55°C to +125°C; V_{DD}=3.0V to 5.5V)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
Supply Voltage	V_{DD}	Local Power	+3.0		+5.5	V	1
Pullup Supply Voltage	V_{PU}	Parasite Power	+3.0		+5.5	V	1,2
		Local Power	+3.0		V_{DD}		
Thermometer Error	t_{ERR}	-10°C to +85°C			±0.5	°C	3
		-55°C to +125°C			±2		
Input Logic-Low	V_{IL}		-0.3		+0.8	V	1,4,5
Input Logic-High	V_{IH}	Local Power	+2.2		The lower of 5.5 or V_{DD} + 0.3	V	1, 6
		Parasite Power	+3.0				
Sink Current	I_L	$V_{I/O}$ = 0.4V	4.0			mA	1
Standby Current	I_{DDS}			750	1000	nA	7,8
Active Current	I_{DD}	V_{DD} = 5V		1	1.5	mA	9
DQ Input Current	I_{DQ}			5		µA	10
Drift				±0.2		°C	11

NOTES:

1) All voltages are referenced to ground.
2) The Pullup Supply Voltage specification assumes that the pullup device is ideal, and therefore the high level of the pullup is equal to V_{PU}. In order to meet the V_{IH} spec of the DS18B20, the actual supply rail for the strong pullup transistor must include margin for the voltage drop across the transistor when it is turned on; thus: $V_{PU_ACTUAL} = V_{PU_IDEAL} + V_{TRANSISTOR}$.
3) See typical performance curve in Figure 17.
4) Logic-low voltages are specified at a sink current of 4mA.
5) To guarantee a presence pulse under low voltage parasite power conditions, V_{ILMAX} may have to be reduced to as low as 0.5V.
6) Logic-high voltages are specified at a source current of 1mA.
7) Standby current specified up to +70°C. Standby current typically is 3µA at +125°C.
8) To minimize I_{DDS}, DQ should be within the following ranges: GND ≤ DQ ≤ GND + 0.3V or V_{DD} – 0.3V ≤ DQ ≤ V_{DD}.
9) Active current refers to supply current during active temperature conversions or EEPROM writes.
10) DQ line is high ("high-Z" state).
11) Drift data is based on a 1000-hour stress test at +125°C with V_{DD} = 5.5V.

AC ELECTRICAL CHARACTERISTICS—NV MEMORY

(-55°C to +100°C; V_{DD} = 3.0V to 5.5V)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
NV Write Cycle Time	t_{WR}			2	10	ms
EEPROM Writes	N_{EEWR}	-55°C to +55°C	50k			writes
EEPROM Data Retention	t_{EEDR}	-55°C to +55°C	10			years

AC ELECTRICAL CHARACTERISTICS (-55°C to +125°C; V_{DD} = 3.0V to 5.5V)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
Temperature Conversion Time	t_{CONV}	9-bit resolution			93.75	ms	1
		10-bit resolution			187.5		
		11-bit resolution			375		
		12-bit resolution			750		
Time to Strong Pullup On	t_{SPON}	Start Convert T Command Issued			10	µs	
Time Slot	t_{SLOT}		60		120	µs	1
Recovery Time	t_{REC}		1			µs	1
Write 0 Low Time	t_{LOW0}		60		120	µs	1
Write 1 Low Time	t_{LOW1}		1		15	µs	1
Read Data Valid	t_{RDV}				15	µs	1
Reset Time High	t_{RSTH}		480			µs	1
Reset Time Low	t_{RSTL}		480			µs	1,2
Presence-Detect High	t_{PDHIGH}		15		60	µs	1
Presence-Detect Low	t_{PDLOW}		60		240	µs	1
Capacitance	$C_{IN/OUT}$				25	pF	

NOTES:

1) See the timing diagrams in Figure 18.
2) Under parasite power, if t_{RSTL} > 960µs, a power-on reset may occur.

Figure 17. Typical Performance Curve

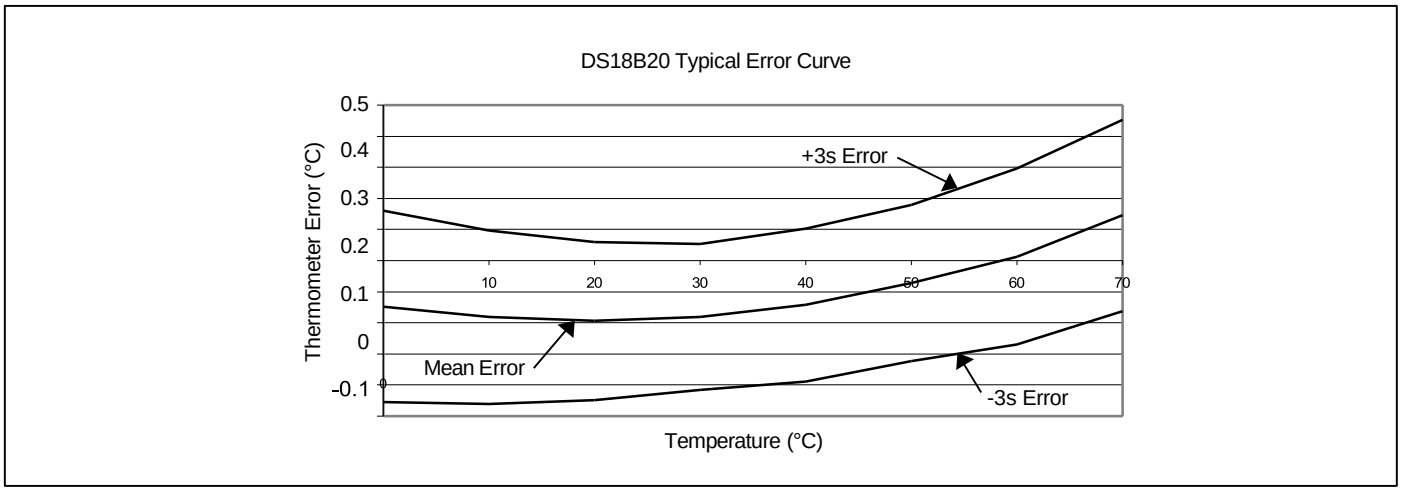
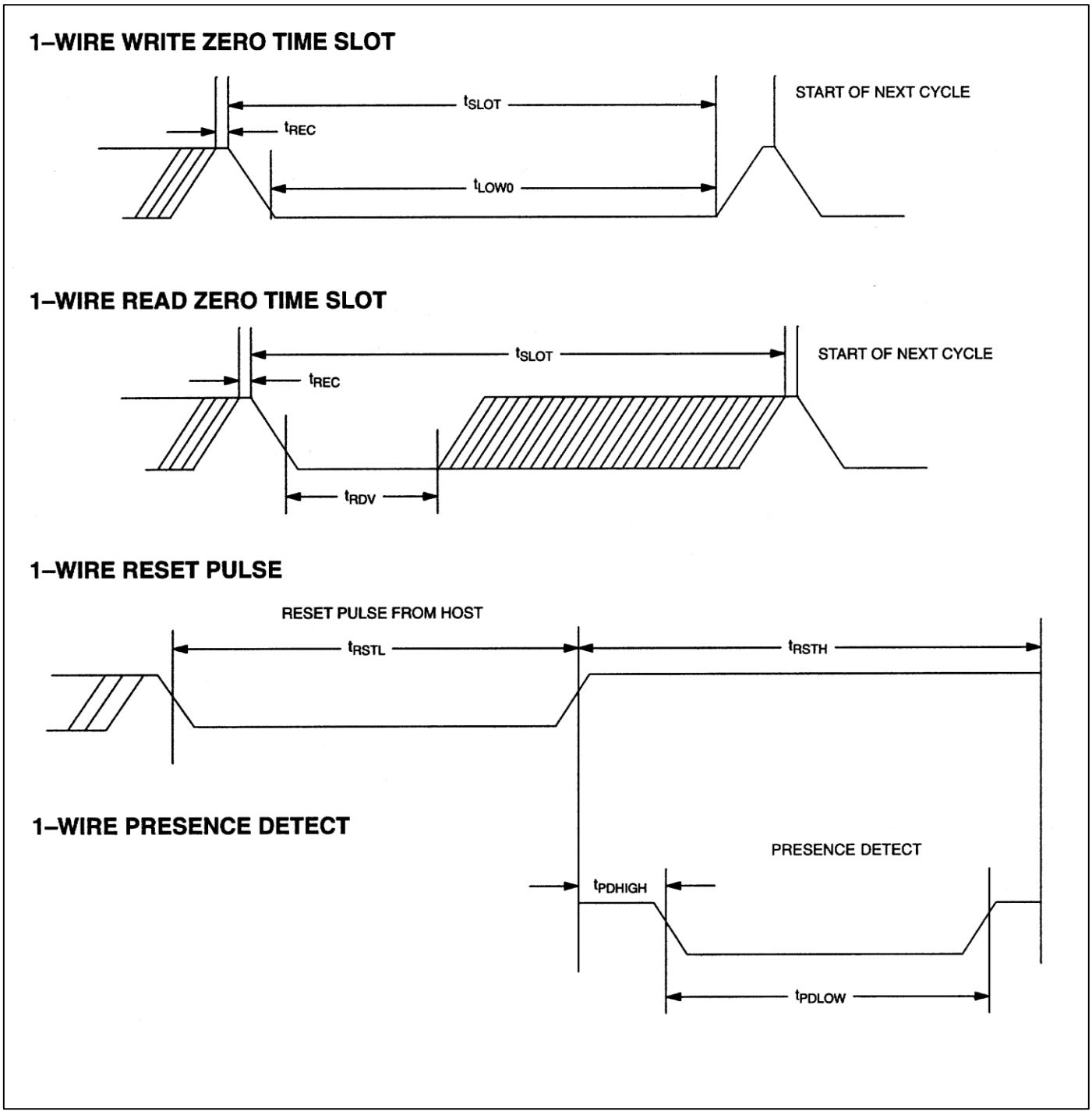


Figure 18. Timing Diagrams



REVISION HISTORY

REVISION DATE	DESCRIPTION	PAGES CHANGED
030107	In the *Absolute Maximum Ratings* section, removed the reflow oven temperature value of +220°C. Reference to JEDEC specification for reflow remains.	19
101207	In the *Operation—Alarm Signaling* section, added "or equal to" in the desciption for a TH alarm condition	5
	In the *Memory* section, removed incorrect text describing memory.	7
	In the *Configuration Register* section, removed incorrect text describing configuration register.	8
042208	In the Ordering Information table, added TO-92 straight-lead packages and included a note that the TO-92 package in tape and reel can be ordered with either formed or straight leads.	2

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RoHS COMPLIANT

LM35

Precision Centigrade Temperature Sensors

General Description

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in ° Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ~~±¼°C~~ at room temperature and ~~±¾°C~~ over a full −55 to +150°C temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies, or with plus and minus supplies. As it draws only 60 µA from its supply, it has very low self-heating, less than 0.1°C in still air. The LM35 is rated to operate over a −55° to +150°C temperature range, while the LM35C is rated for a −40° to +110°C range (−10° with improved accuracy). The LM35 series is available packaged in hermetic TO-46 transistor packages, while the LM35C, LM35CA, and LM35D are also available in the plastic TO-92 transistor package. The LM35D is also available in an 8-lead surface mount small outline package and a plastic TO-220 package.

Features

- Calibrated directly in ° Celsius (Centigrade)
- Linear + 10.0 mV/°C scale factor
- 0.5°C accuracy guaranteeable (at +25°C)
- Rated for full −55° to +150°C range
- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operates from 4 to 30 volts
- Less than 60 µA current drain
- Low self-heating, 0.08°C in still air
- Nonlinearity only ~~±¼°C~~ typical
- Low impedance output, 0.1 Ω for 1 mA load

Typical Applications

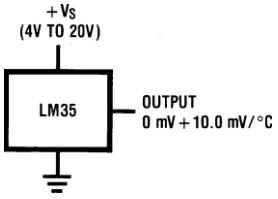
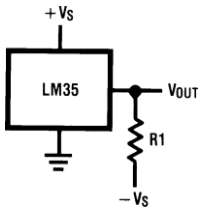


FIGURE 1. Basic Centigrade Temperature Sensor (+2°C to +150°C)

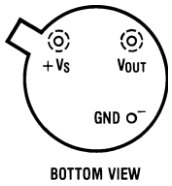


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Connection Diagrams

TO-46

Metal Can Package*



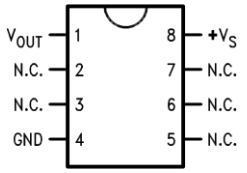
DS005516-1

*Case is connected to negative pin (GND)

Order Number LM35H, LM35AH, LM35CH, LM35CAH or LM35DH

SO-8

Small Outline Molded Package



DS005516-21

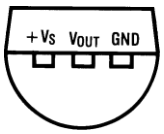
N.C. = No Connection

Top View

Order Number LM35DM

TO-92

Plastic Package

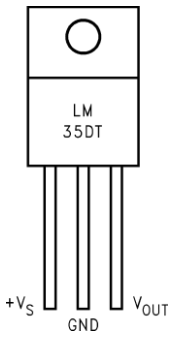


DS005516-2

Order Number LM35CZ, LM35CAZ or LM35DZ

TO-220

Plastic Package*



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Absolute Maximum Ratings (Note 10)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Supply Voltage	+35V to −0.2V
Output Voltage	+6V to −1.0V
Output Current	10 mA
Storage Temp.;	
TO-46 Package,	−60˚C to +180˚C
TO-92 Package,	−60˚C to +150˚C
SO-8 Package,	−65˚C to +150˚C
TO-220 Package,	−65˚C to +150˚C
Lead Temp.:	
TO-46 Package, (Soldering, 10 seconds)	300˚C
TO-92 and TO-220 Package, (Soldering, 10 seconds)	260˚C
SO Package (Note 12)	
Vapor Phase (60 seconds)	215˚C
Infrared (15 seconds)	220˚C
ESD Susceptibility (Note 11)	2500V
Specified Operating Temperature Range: T_{MIN} to T_{MAX} (Note 2)	
LM35, LM35A	−55˚C to +150˚C
LM35C, LM35CA	−40˚C to +110˚C
LM35D	0˚C to +100˚C

Electrical Characteristics

(Notes 1, 6)

Parameter	Conditions	LM35A			LM35CA			Units (Max.)
		Typical	Tested Limit (Note 4)	Design Limit (Note 5)	Typical	Tested Limit (Note 4)	Design Limit (Note 5)	
Accuracy	T_A=+25˚C	±0.2	±0.5		±0.2	±0.5		˚C
(Note 7)	T_A=−10˚C	±0.3			±0.3		±1.0	˚C
	T_A=T_{MAX}	±0.4	±1.0		±0.4	±1.0		˚C
	T_A=T_{MIN}	±0.4	±1.0		±0.4		±1.5	˚C
Nonlinearity (Note 8)	T_{MIN}≤T_A≤T_{MAX}	**±0.18**		**±0.35**	**±0.15**		**±0.3**	˚C
Sensor Gain (Average Slope)	T_{MIN}≤T_A≤T_{MAX}	**+10.0**	**+9.9, +10.1**		**+10.0**		**+9.9, +10.1**	mV/˚C
Load Regulation (Note 3) 0≤I_L≤1 mA	T_A=+25˚C	±0.4	±1.0		±0.4	±1.0		mV/mA
	T_{MIN}≤T_A≤T_{MAX}	**±0.5**		**±3.0**	**±0.5**		**±3.0**	mV/mA
Line Regulation (Note 3)	T_A=+25˚C	±0.01	±0.05		±0.01	±0.05		mV/V
	4V≤V_S≤30V	**±0.02**		**±0.1**	**±0.02**		**±0.1**	mV/V
Quiescent Current (Note 9)	V_S=+5V, +25˚C	56	67		56	67		µA
	V_S=+5V	**105**		**131**	**91**		**114**	µA
	V_S=+30V, +25˚C	56.2	68		56.2	68		µA
	V_S=+30V	**105.5**		**133**	**91.5**		**116**	µA
Change of Quiescent Current (Note 3)	4V≤V_S≤30V, +25˚C	0.2	1.0		0.2	1.0		µA
	4V≤V_S≤30V	**0.5**		**2.0**	**0.5**		**2.0**	µA
Temperature Coefficient of Quiescent Current		**+0.39**		**+0.5**	**+0.39**		**+0.5**	µA/˚C
Minimum Temperature for Rated Accuracy	In circuit of *Figure 1*, I_L=0	+1.5		+2.0	+1.5		+2.0	˚C
Long Term Stability	T_J=T_{MAX}, for 1000 hours	±0.08			±0.08			˚C

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Electrical Characteristics

(Notes 1, 6)

Parameter	Conditions	LM35			LM35C, LM35D			Units (Max.)
		Typical	Tested Limit (Note 4)	Design Limit (Note 5)	Typical	Tested Limit (Note 4)	Design Limit (Note 5)	
Accuracy,	T_A=+25˚C	±0.4	±1.0		±0.4	±1.0		˚C
LM35, LM35C	T_A=−10˚C	±0.5			±0.5		±1.5	˚C
(Note 7)	T_A=T_{MAX}	±0.8	±1.5		±0.8		±1.5	˚C
	T_A=T_{MIN}	±0.8		±1.5	±0.8		±2.0	˚C
Accuracy, LM35D	T_A=+25˚C				±0.6	±1.5		˚C
(Note 7)	T_A=T_{MAX}				±0.9		±2.0	˚C
	T_A=T_{MIN}				±0.9		±2.0	˚C
Nonlinearity	T_{MIN}≤T_A≤T_{MAX}	**±0.3**		**±0.5**	**±0.2**		**±0.5**	˚C
(Note 8)								
Sensor Gain	T_{MIN}≤T_A≤T_{MAX}	**+10.0**	**+9.8, +10.2**		**+10.0**		**+9.8, +10.2**	mV/˚C
(Average Slope)								
Load Regulation	T_A=+25˚C	±0.4	±2.0		±0.4	±2.0		mV/mA
(Note 3) 0≤I_L≤1 mA	T_{MIN}≤T_A≤T_{MAX}	**±0.5**		**±5.0**	**±0.5**		**±5.0**	mV/mA
Line Regulation	T_A=+25˚C	±0.01	±0.1		±0.01	±0.1		mV/V
(Note 3)	4V≤V_S≤30V	**±0.02**		**±0.2**	**±0.02**		**±0.2**	mV/V
Quiescent Current	V_S=+5V, +25˚C	56	80		56	80		µA
(Note 9)	V_S=+5V	**105**		**158**	**91**		**138**	µA
	V_S=+30V, +25˚C	56.2	82		56.2	82		µA
	V_S=+30V	**105.5**		**161**	**91.5**		**141**	µA
Change of	4V≤V_S≤30V, +25˚C	0.2	2.0		0.2	2.0		µA
Quiescent Current	4V≤V_S≤30V	**0.5**		**3.0**	**0.5**		**3.0**	µA
(Note 3)								
Temperature Coefficient of Quiescent Current		**+0.39**		**+0.7**	**+0.39**		**+0.7**	µA/˚C
Minimum Temperature	In circuit of	+1.5		+2.0	+1.5		+2.0	˚C
for Rated Accuracy	*Figure 1*, I_L=0							
Long Term Stability	T_J=T_{MAX}, for	±0.08			±0.08			˚C
	1000 hours							

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Note 1: Unless otherwise noted, these specifications apply: −55˚C≤T_J≤+150˚C for the LM35 and LM35A; −40≤˚ T_J≤+110˚C for the LM35C and LM35CA; and 0˚≤T_J≤+100˚C for the LM35D. V_S=+5Vdc and I_{LOAD}=50 μA, in the circuit of *Figure 2*. These specifications also apply from +2˚C to T_{MAX} in the circuit of *Figure 1*. Specifications in **boldface** apply over the full rated temperature range.

Note 2: Thermal resistance of the TO-46 package is 400˚C/W, junction to ambient, and 24˚C/W junction to case. Thermal resistance of the TO-92 package is 180˚C/W junction to ambient. Thermal resistance of the small outline molded package is 220˚C/W junction to ambient. Thermal resistance of the TO-220 package is 90˚C/W junction to ambient. For additional thermal resistance information see table in the Applications section.

Note 3: Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output due to heating effects can be computed by multiplying the internal dissipation by the thermal resistance.

Note 4: Tested Limits are guaranteed and 100% tested in production.

Note 5: Design Limits are guaranteed (but not 100% production tested) over the indicated temperature and supply voltage ranges. These limits are not used to calculate outgoing quality levels.

Note 6: Specifications in **boldface** apply over the full rated temperature range.

Note 7: Accuracy is defined as the error between the output voltage and 10mv/˚C times the device's case temperature, at specified conditions of voltage, current, and temperature (expressed in ˚C).

Note 8: Nonlinearity is defined as the deviation of the output-voltage-versus-temperature curve from the best-fit straight line, over the device's rated temperature range.

Note 9: Quiescent current is defined in the circuit of *Figure 1*.

Note 10: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications do not apply when operating the device beyond its rated operating conditions. See Note 1.

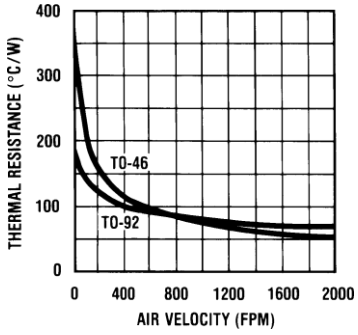
Note 11: Human body model, 100 pF discharged through a 1.5 kΩ resistor.

Note 12: See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" or the section titled "Surface Mount" found in a current National Semiconductor Linear Data Book for other methods of soldering surface mount devices.

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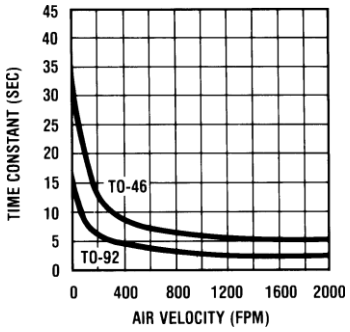
Typical Performance Characteristics

Thermal Resistance Junction to Air



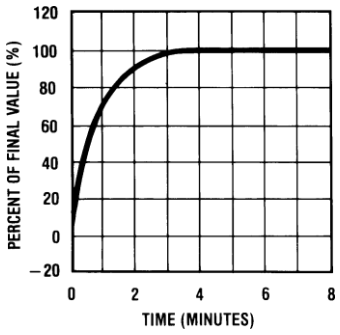
DS005516-25

Thermal Time Constant



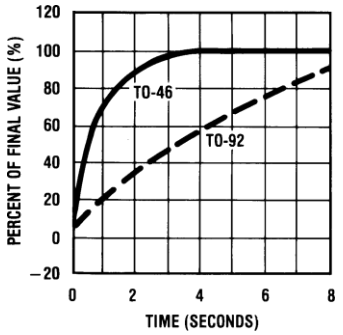
DS005516-26

Thermal Response in Still Air



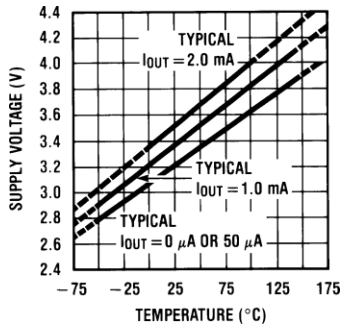
DS005516-27

Thermal Response in Stirred Oil Bath



DS005516-28

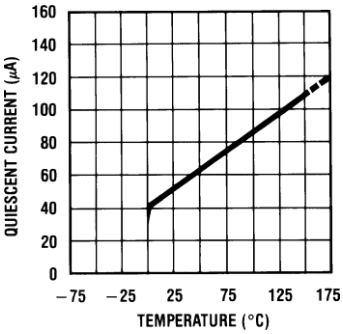
Minimum Supply Voltage vs. Temperature



DS005516-29

Quiescent Current vs. Temperature

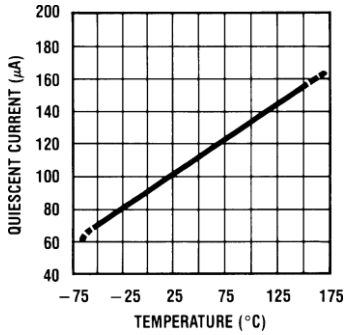
(In Circuit of *Figure 1*.)



DS005516-30

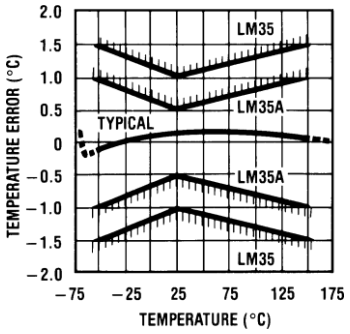
Quiescent Current vs. Temperature

(In Circuit of *Figure 2*.)



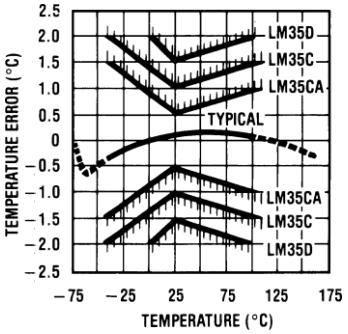
DS005516-31

Accuracy vs. Temperature (Guaranteed)



DS005516-32

Accuracy vs. Temperature (Guaranteed)

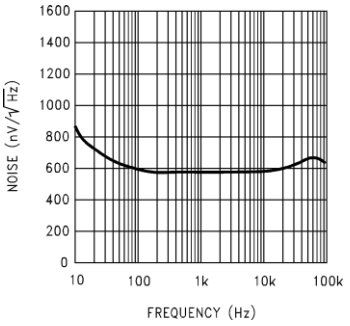


DS005516-33

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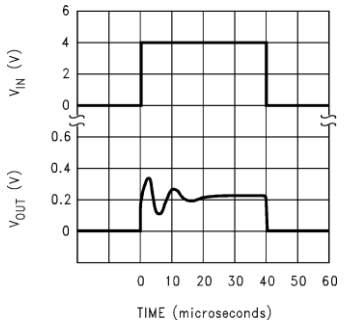
Typical Performance Characteristics (Continued)

Noise Voltage



DS005516-34

Start-Up Response



DS005516-35

Applications

The LM35 can be applied easily in the same way as other integrated-circuit temperature sensors. It can be glued or cemented to a surface and its temperature will be within about 0.01˚C of the surface temperature.

This presumes that the ambient air temperature is almost the same as the surface temperature; if the air temperature were much higher or lower than the surface temperature, the actual temperature of the LM35 die would be at an intermediate temperature between the surface temperature and the air temperature. This is expecially true for the TO-92 plastic package, where the copper leads are the principal thermal path to carry heat into the device, so its temperature might be closer to the air temperature than to the surface temperature.

To minimize this problem, be sure that the wiring to the LM35, as it leaves the device, is held at the same tempera- ture as the surface of interest. The easiest way to do this is to cover up these wires with a bead of epoxy which will insure that the leads and wires are all at the same tempera- ture as the surface, and that the LM35 die's temperature will not be affected by the air temperature.

The TO-46 metal package can also be soldered to a metal surface or pipe without damage. Of course, in that case the

V− terminal of the circuit will be grounded to that metal. Alternatively, the LM35 can be mounted inside a sealed-end metal tube, and can then be dipped into a bath or screwed into a threaded hole in a tank. As with any IC, the LM35 and accompanying wiring and circuits must be kept insulated and dry, to avoid leakage and corrosion. This is especially true if the circuit may operate at cold temperatures where condensation can occur. Printed-circuit coatings and varnishes such as Humiseal and epoxy paints or dips are often used to insure that moisture cannot corrode the LM35 or its connections.

These devices are sometimes soldered to a small light-weight heat fin, to decrease the thermal time constant and speed up the response in slowly-moving air. On the other hand, a small thermal mass may be added to the sensor, to give the steadiest reading despite small deviations in the air temperature.

Temperature Rise of LM35 Due To Self-heating (Thermal Resistance, θ_{JA})

	TO-46, no heat sink	TO-46*, small heat fin	TO-92, no heat sink	TO-92**, small heat fin	SO-8 no heat sink	SO-8** small heat fin	TO-220 no heat sink
Still air	400˚C/W	100˚C/W	180˚C/W	140˚C/W	220˚C/W	110˚C/W	90˚C/W
Moving air	100˚C/W	40˚C/W	90˚C/W	70˚C/W	105˚C/W	90˚C/W	26˚C/W
Still oil	100˚C/W	40˚C/W	90˚C/W	70˚C/W			
Stirred oil	50˚C/W	30˚C/W	45˚C/W	40˚C/W			
(Clamped to metal, Infinite heat sink)		(24˚C/W)				(55˚C/W)	

*Wakefield type 201, or 1" disc of 0.020" sheet brass, soldered to case, or similar.

**TO-92 and SO-8 packages glued and leads soldered to 1" square of 1/16" printed circuit board with 2 oz. foil or similar.

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Typical Applications

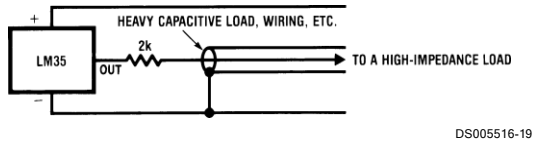


FIGURE 3. LM35 with Decoupling from Capacitive Load

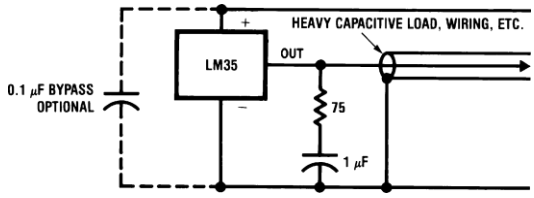


FIGURE 4. LM35 with R-C Damper

CAPACITIVE LOADS

Like most micropower circuits, the LM35 has a limited ability to drive heavy capacitive loads. The LM35 by itself is able to drive 50 pf without special precautions. If heavier loads are anticipated, it is easy to isolate or decouple the load with a resistor; see *Figure 3*. Or you can improve the tolerance of capacitance with a series R-C damper from output to ground; see *Figure 4*.

When the LM35 is applied with a 200Ω load resistor as shown in *Figure 5*, *Figure 6* or *Figure 8* it is relatively immune to wiring capacitance because the capacitance forms a by- pass from ground to input, not on the output. However, as with any linear circuit connected to wires in a hostile envi- ronment, its performance can be affected adversely by in- tense electromagnetic sources such as relays, radio trans- mitters, motors with arcing brushes, SCR transients, etc, as its wiring can act as a receiving antenna and its internal junctions can act as rectifiers. For best results in such cases, a bypass capacitor from V_{IN} to ground and a series R-C damper such as 75Ω in series with 0.2 or 1 μF from output to ground are often useful. These are shown in *Figure 13*, *Figure 14*, and *Figure 16*.

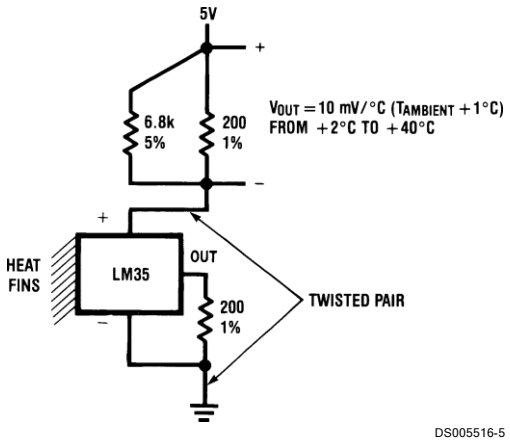


FIGURE 5. Two-Wire Remote Temperature Sensor (Grounded Sensor)

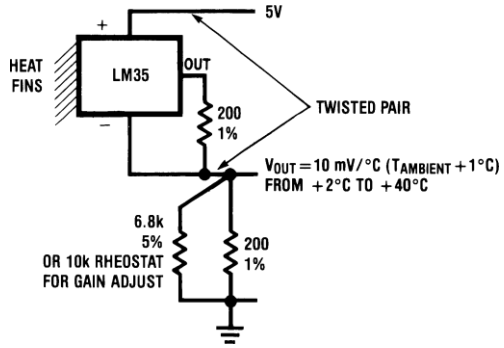


FIGURE 6. Two-Wire Remote Temperature Sensor (Output Referred to Ground)

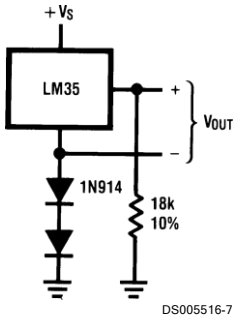


FIGURE 7. Temperature Sensor, Single Supply, −55˚ to +150˚C

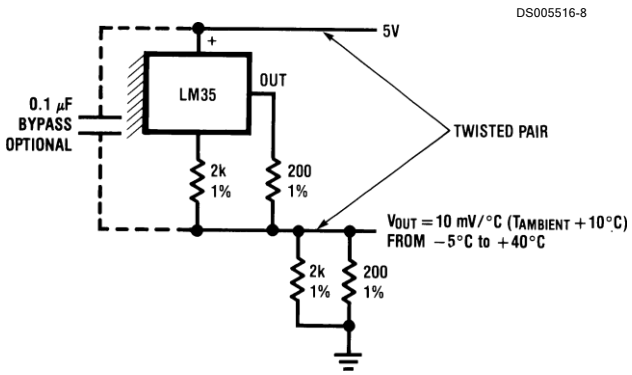
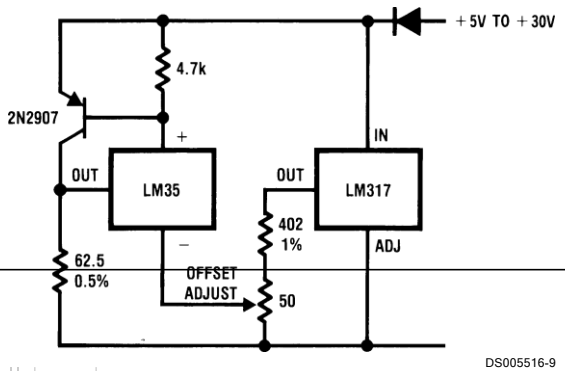


FIGURE 8. Two-Wire Remote Temperature Sensor (Output Referred to Ground)



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Typical Applications

FIGURE 9. 4-To-20 mA Current Source (0˚C to +100˚C)

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Typical Applications (Continued)

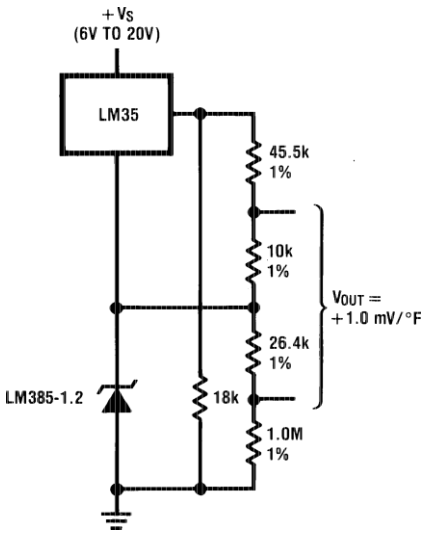


FIGURE 10. Fahrenheit Thermometer

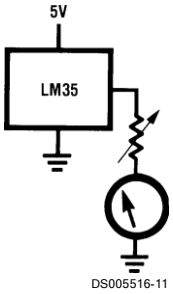


FIGURE 11. Centigrade Thermometer (Analog Meter)

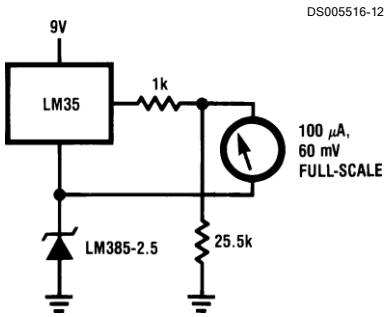


FIGURE 12. Fahrenheit ThermometerExpanded Scale Thermometer

(50˚ to 80˚ Fahrenheit, for Example Shown)

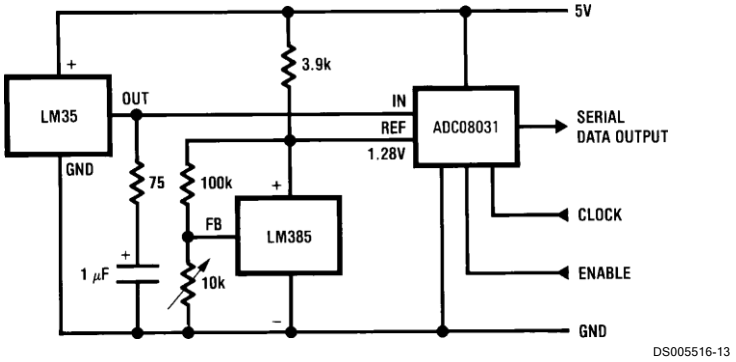


FIGURE 13. Temperature To Digital Converter (Serial Output) (+128˚C Full Scale)

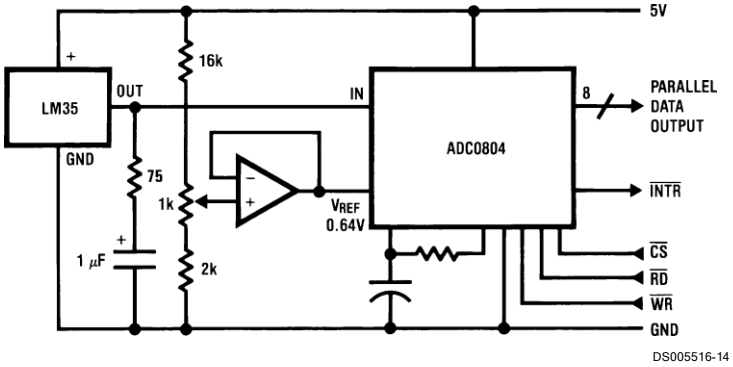
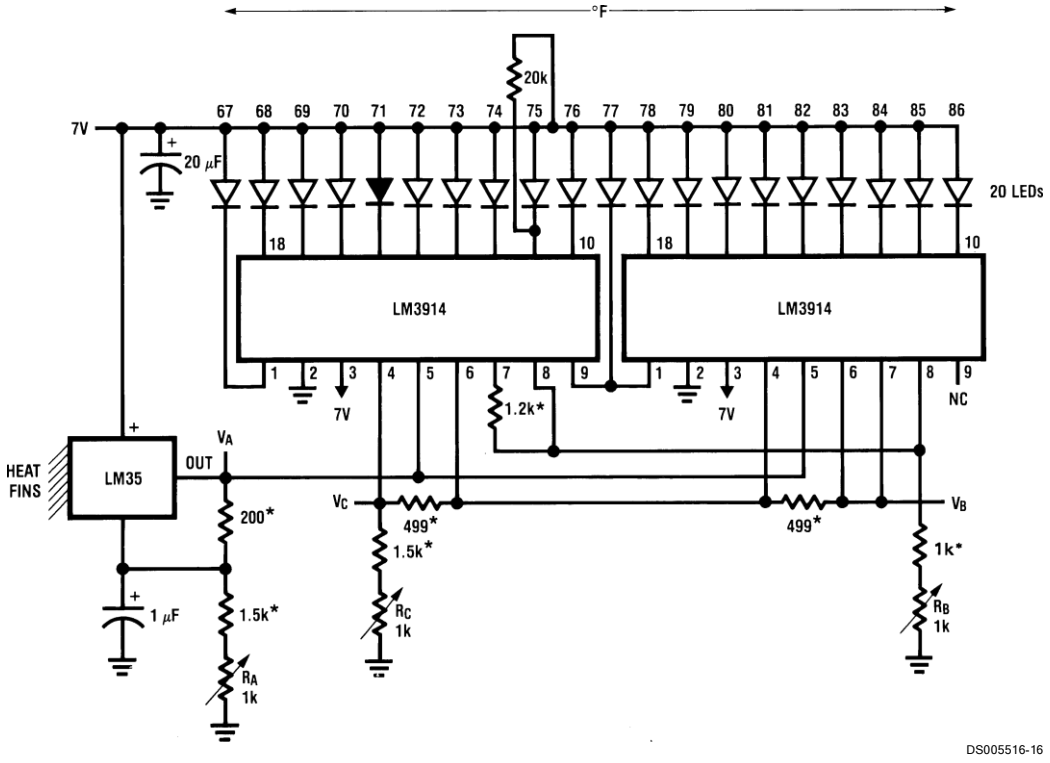


FIGURE 14. Temperature To Digital Converter (Parallel TRI-STATE™ Outputs for Standard Data Bus to µP Interface) (128˚C Full Scale)

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Typical Applications (Continued)



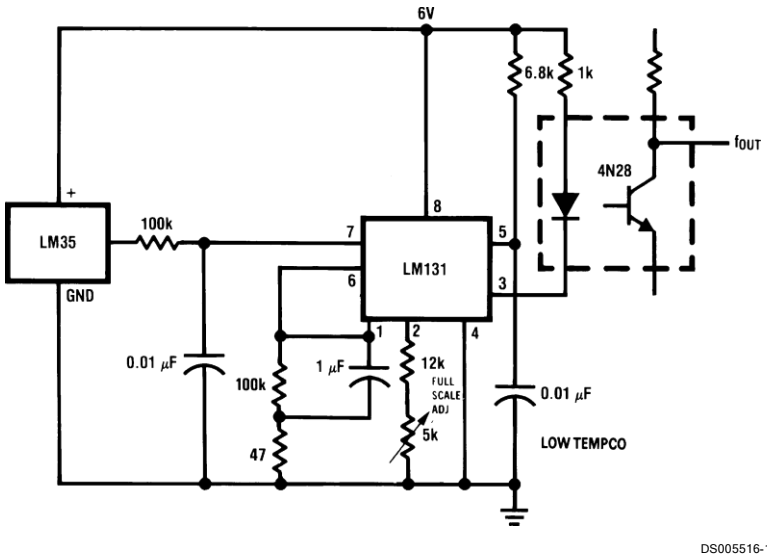
DS005516-16

*=1% or 2% film resistor
Trim R_B for V_B=3.075V
Trim R_C for V_C=1.955V

Trim R_A for V_A=0.075V + 100mV/˚C x $T_{ambient}$

Example, V_A=2.275V at 22˚C

FIGURE 15. Bar-Graph Temperature Display (Dot Mode)

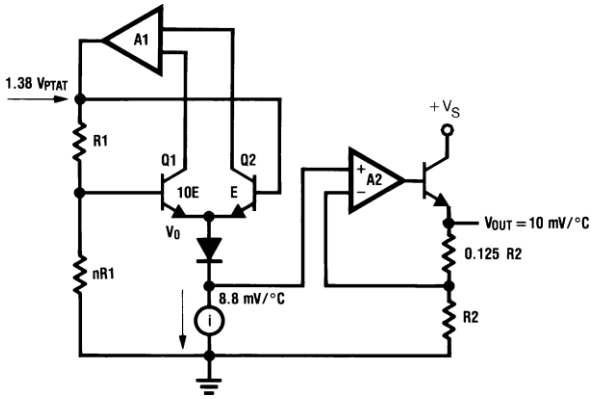


DS005516-15

FIGURE 16. LM35 With Voltage-To-Frequency Converter And Isolated Output (2˚C to +150˚C; 20 Hz to 1500 Hz)

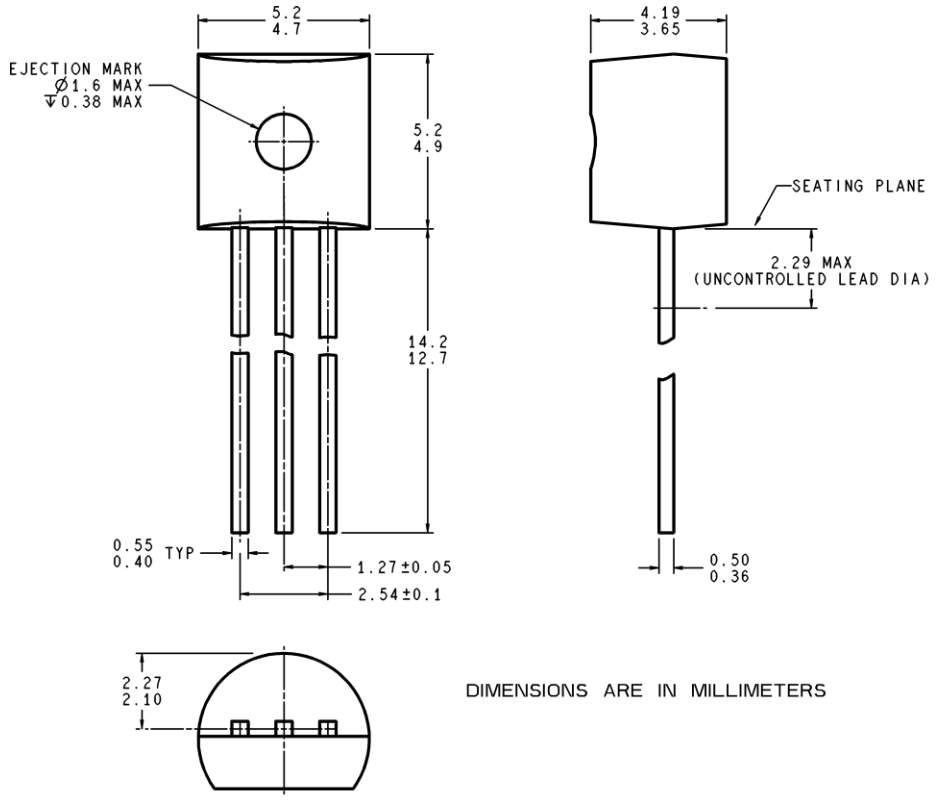
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Block Diagram



DS005516-23

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



Z03A (Rev G)

TO-92 Plastic Package (Z)

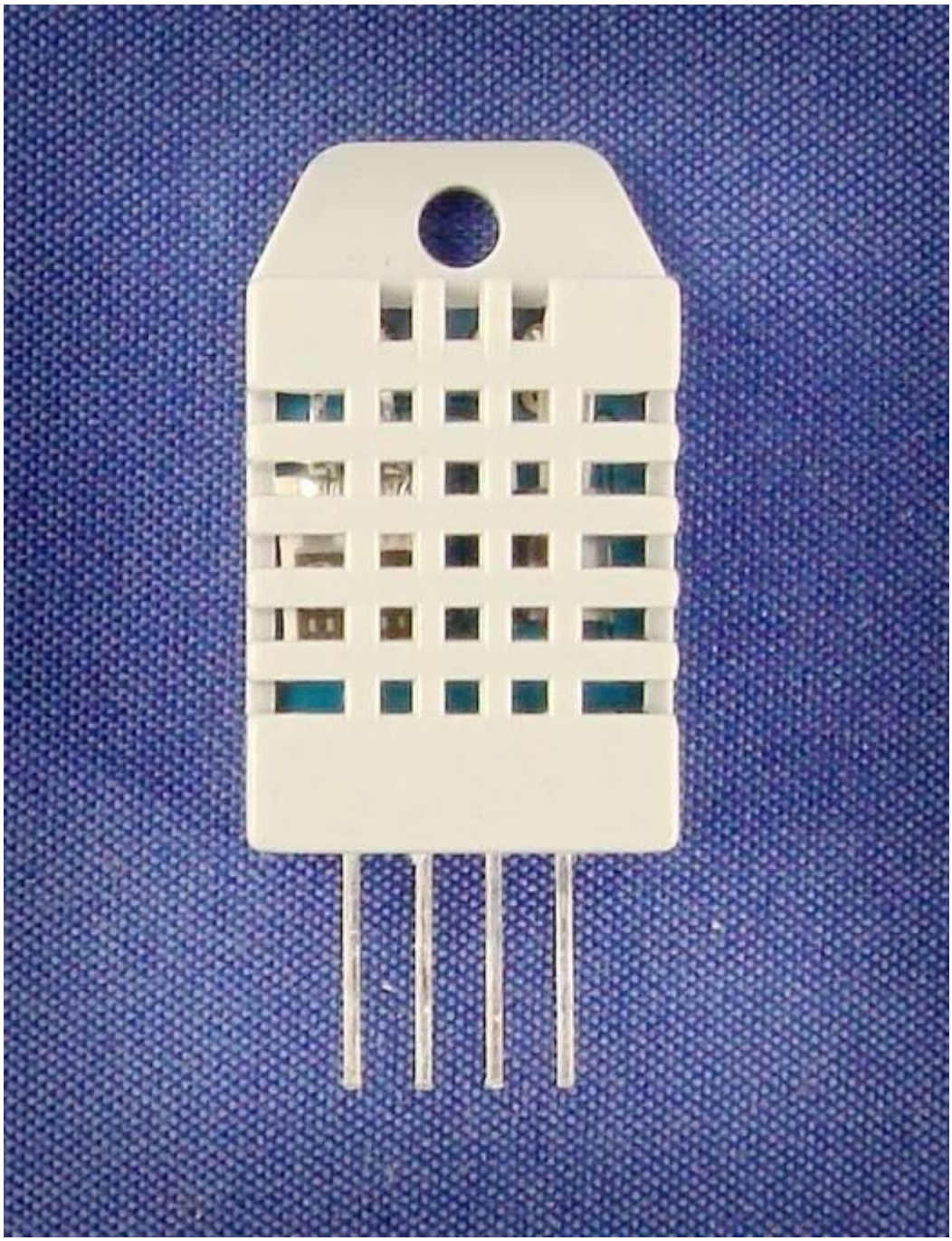
Order Number LM35CZ, LM35CAZ or LM35DZ

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Aosong Electronics Co.,Ltd

Your specialist in innovating humidity & temperature sensors

Digital-output relative humidity & temperature sensor/module DHT22 (DHT22 also named as AM2302)



Capacitive-type humidity and temperature module/sensor

Thomas Liu (Business Manager)

Email: thomasliu198518@yahoo.com.cn

Aosong Electronics Co.,Ltd

Your specialist in innovating humidity & temperature sensors

1. Feature & Application:

* Full range temperature compensated * Relative humidity and temperature measurement
* Calibrated digital signal *Outstanding long-term stability *Extra components not needed
* Long transmission distance * Low power consumption *4 pins packaged and fully interchangeable

2. Description:

DHT22 output calibrated digital signal. It utilizes exclusive digital-signal-collecting-technique and humidity sensing technology, assuring its reliability and stability.Its sensing elements is connected with 8-bit single-chip computer.

Every sensor of this model is temperature compensated and calibrated in accurate calibration chamber and the calibration-coefficient is saved in type of programme in OTP memory, when the sensor is detecting, it will cite coefficient from memory.

Small size & low consumption & long transmission distance(20m) enable DHT22 to be suited in all kinds of harsh application occasions.

Single-row packaged with four pins, making the connection very convenient.

3. Technical Specification:

Model	DHT22
Power supply	3.3-6V DC
Output signal	digital signal via single-bus
Sensing element	Polymer capacitor
Operating range	humidity 0-100%RH; temperature -40~80Celsius
Accuracy	humidity +-2%RH(Max +-5%RH); temperature <+-0.5Celsius
Resolution or sensitivity	humidity 0.1%RH; temperature 0.1Celsius
Repeatability	humidity +-1%RH; temperature +-0.2Celsius
Humidity hysteresis	+-0.3%RH
Long-term Stability	+-0.5%RH/year
Sensing period	Average: 2s
Interchangeability	fully interchangeable
Dimensions	small size 14*18*5.5mm; big size 22*28*5mm

4. Dimensions: (unit ---- mm)

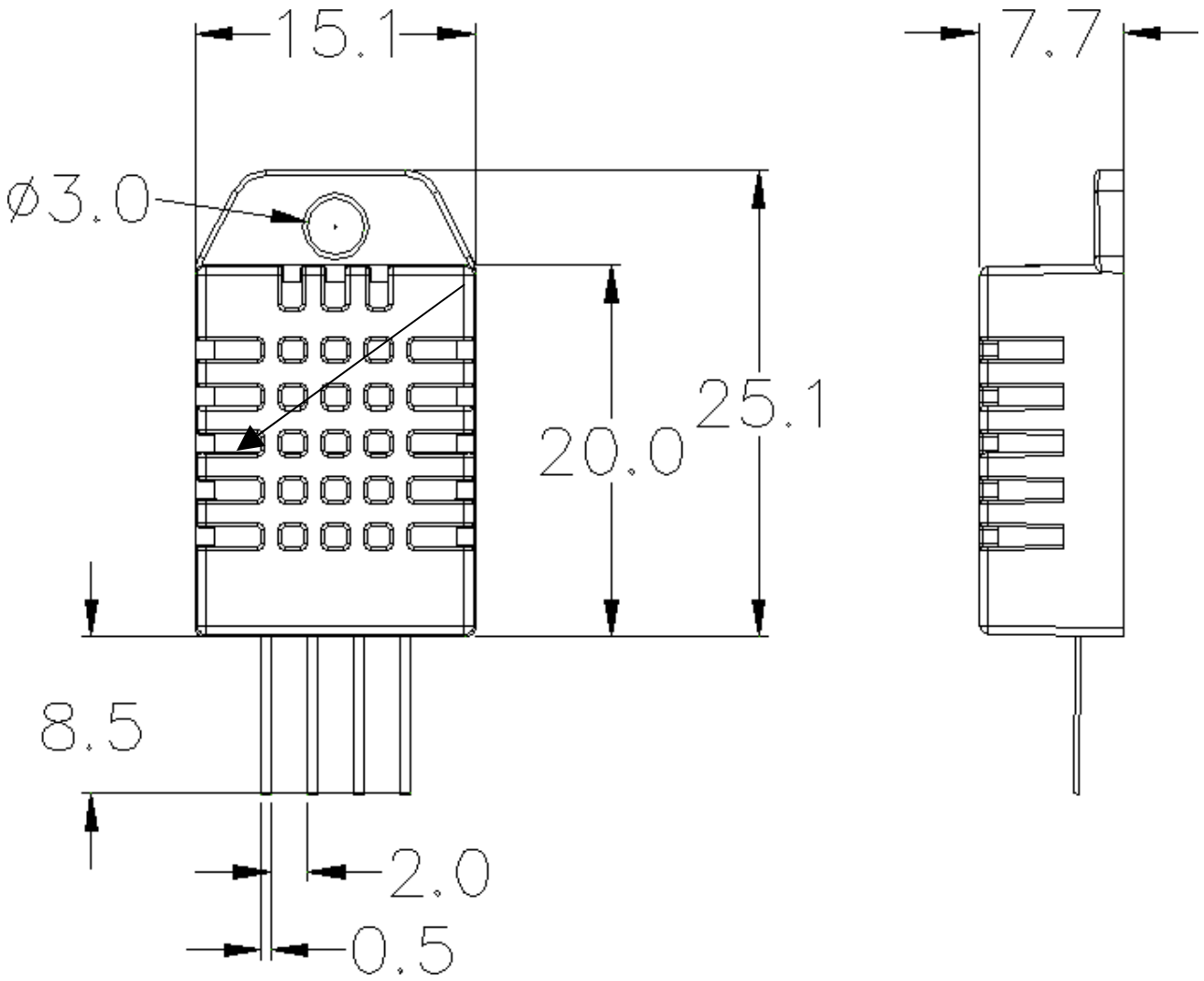
1) Small size dimensions: (unit----- mm)

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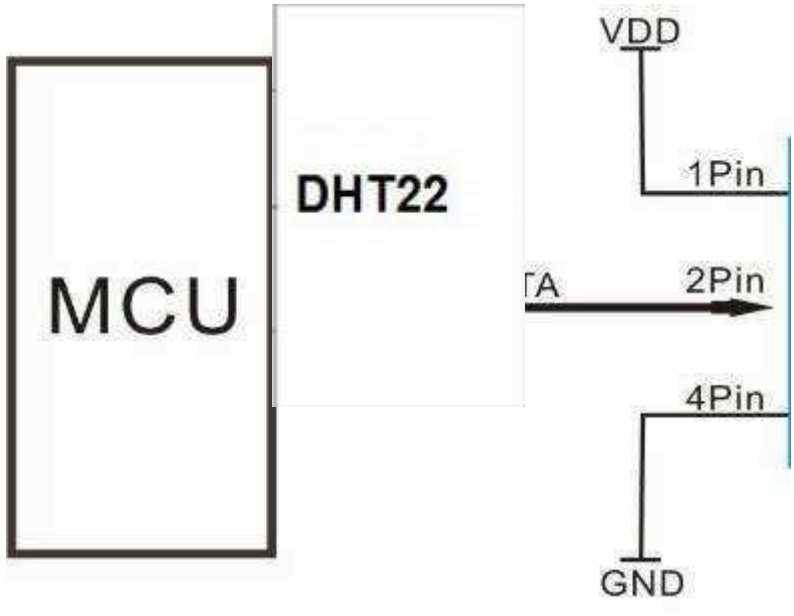
Pin sequence number: 1 2 3 4 (from left to right direction).

Pin	Function
1	VDD --- power supply
2	DATA--signal
3	NULL
4	GND

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5. Electrical connection diagram:



3Pin---NC, AM2302 is another name for DHT22

6. Operating specifications:

(1) Power and Pins

Power's voltage should be 3.3-6V DC. When power is supplied to sensor, don't send any instruction to the sensor within one second to pass unstable status. One capacitor valued 100nF can be added between VDD and GND for wave filtering.

(2) Communication and signal

Single-bus data is used for communication between MCU and DHT22, it costs 5mS for single time communication.

Data is comprised of integral and decimal part, the following is the formula for data.

DHT22 send out higher data bit firstly!

DATA=8 bit integral RH data+8 bit decimal RH data+8 bit integral T data+8 bit decimal T data+8 bit check-sum

If the data transmission is right, check-sum should be the last 8 bit of "8 bit integral RH data+8 bit decimal RH data+8 bit integral T data+8 bit decimal T data".

When MCU send start signal, DHT22 change from low-power-consumption-mode to running-mode. When MCU

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finishs sending the start signal, DHT22 will send response signal of 40-bit data that reflect the relative humidity

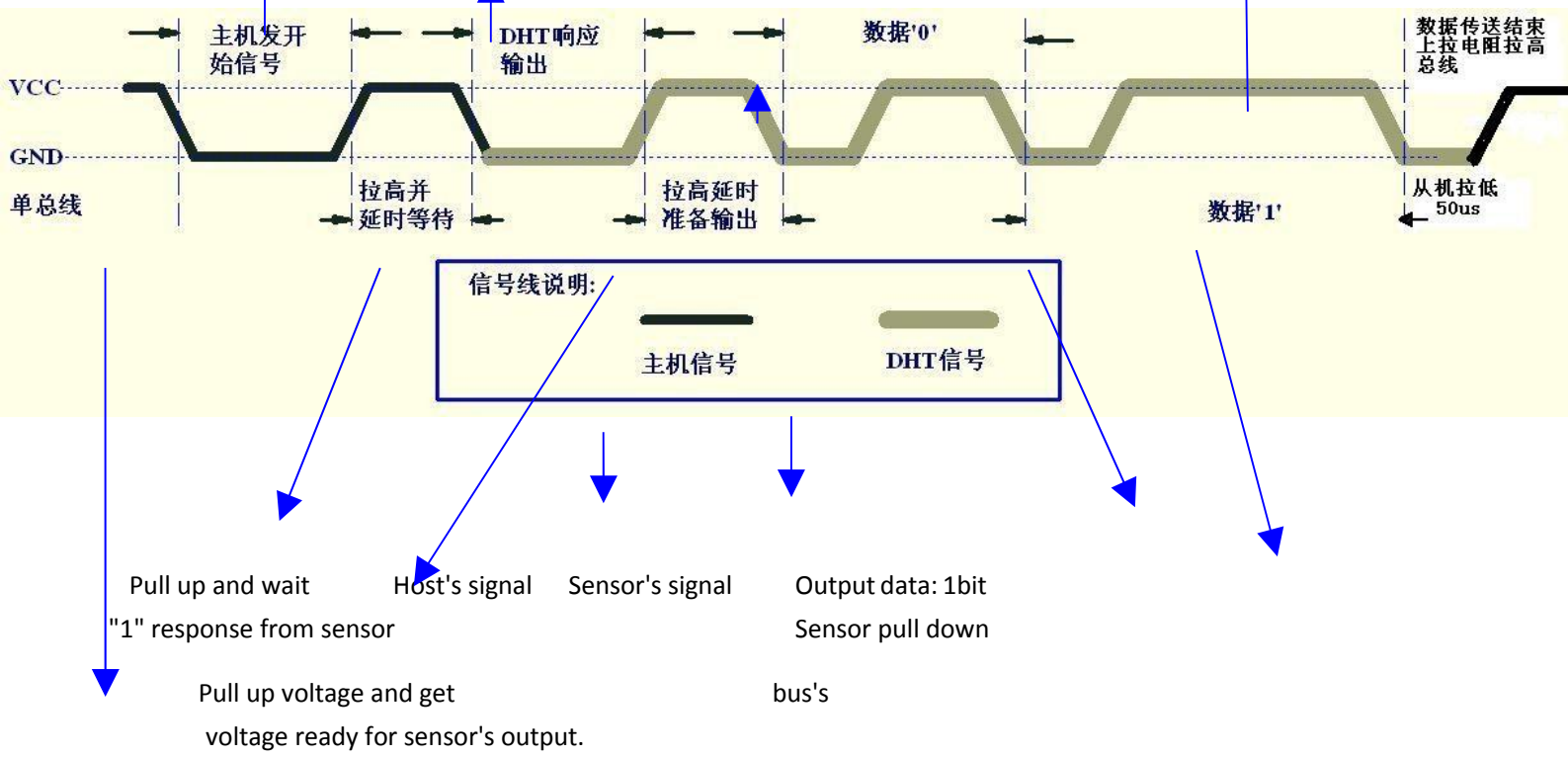
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and temperature information to MCU. Without start signal from MCU, DHT22 will not give response signal to MCU. One start signal for one time's response data that reflect the relative humidity and temperature information from DHT22. DHT22 will change to low-power-consumption-mode when data collecting finish if it don't receive start signal from MCU again.

1) Check bellow picture for overall communication process:



Single-bus output

2) Step 1: MCU send out start signal to DHT22

Data-bus's free status is high voltage level. When communication between MCU and DHT22 begin, program of MCU will transform data-bus's voltage level from high to low level and this process must beyond at least 1ms to ensure DHT22 could detect MCU's signal, then MCU will wait 20-40us for DHT22's response.

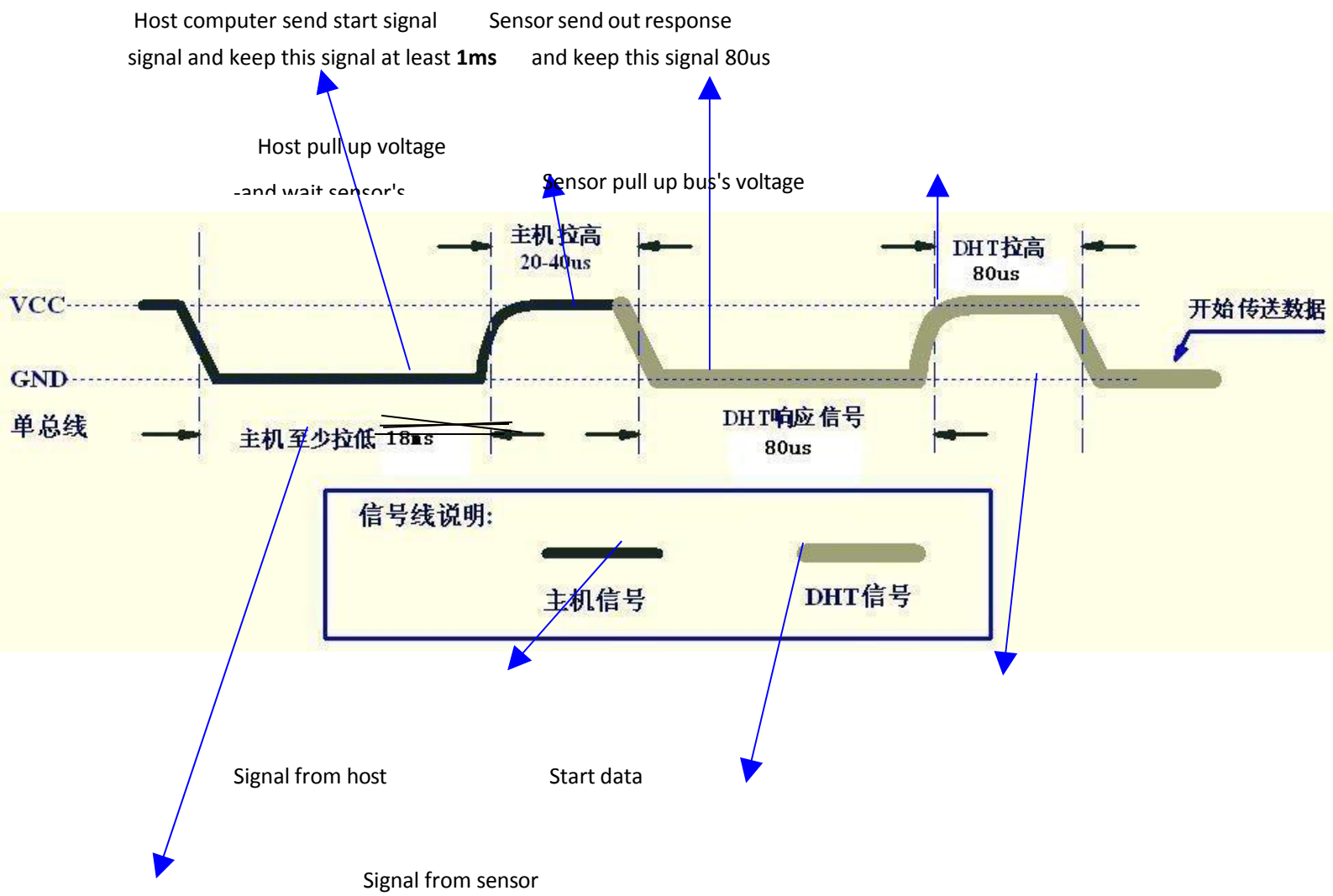
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Check bellow picture for step 1:

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Single-bus signal

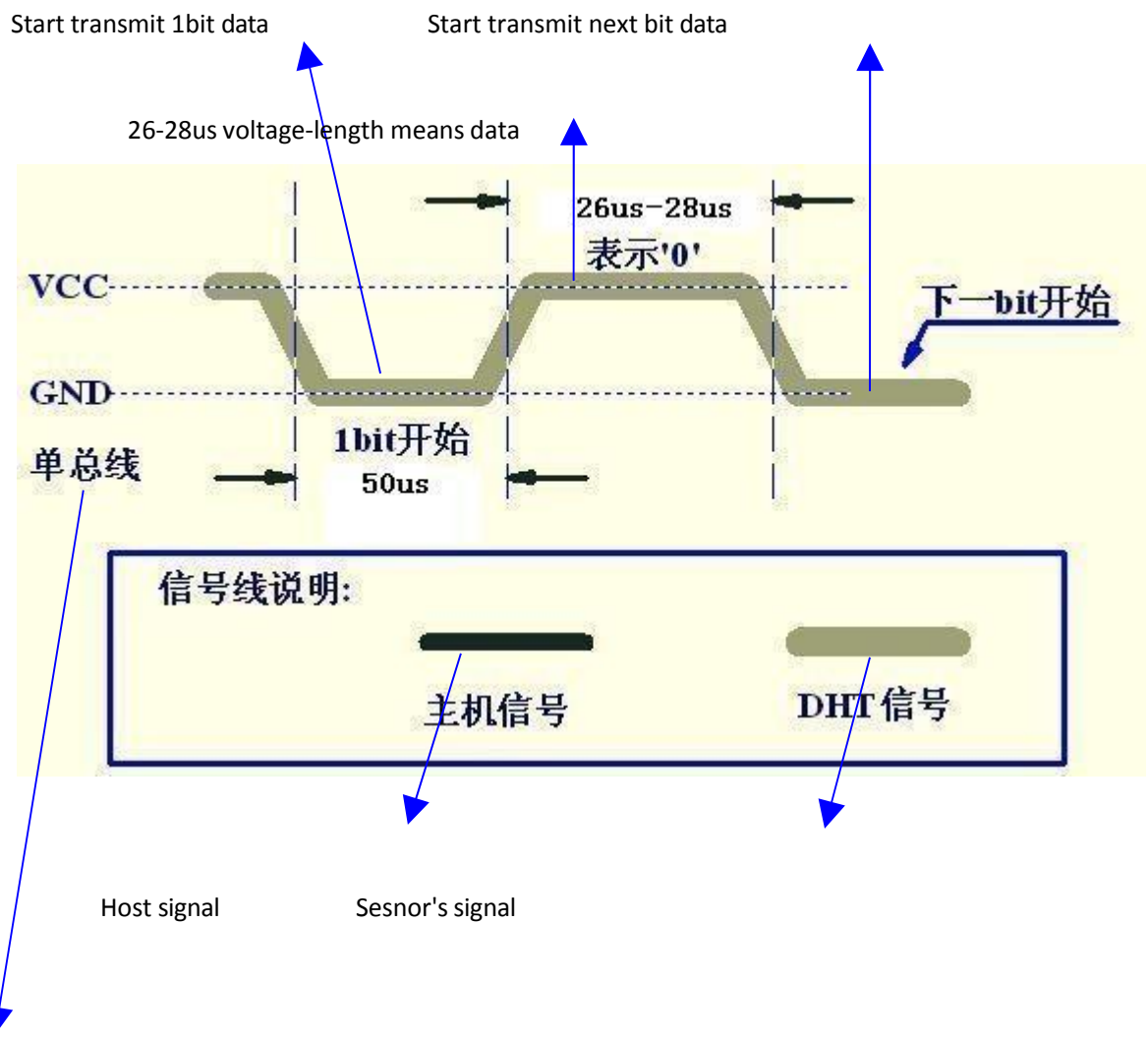
Step 2: DHT22 send response signal to MCU

When DHT22 detect the start signal, DHT22 will send out low-voltage-level signal and this signal last 80us as response signal, then program of DHT22 transform data-bus's voltage level from low to high level and last 80us for DHT22's preparation to send data.

Check bellow picture for step 2:

Thomas Liu (Business Manager)

Email: thomasliu198518@yahoo.com.cn



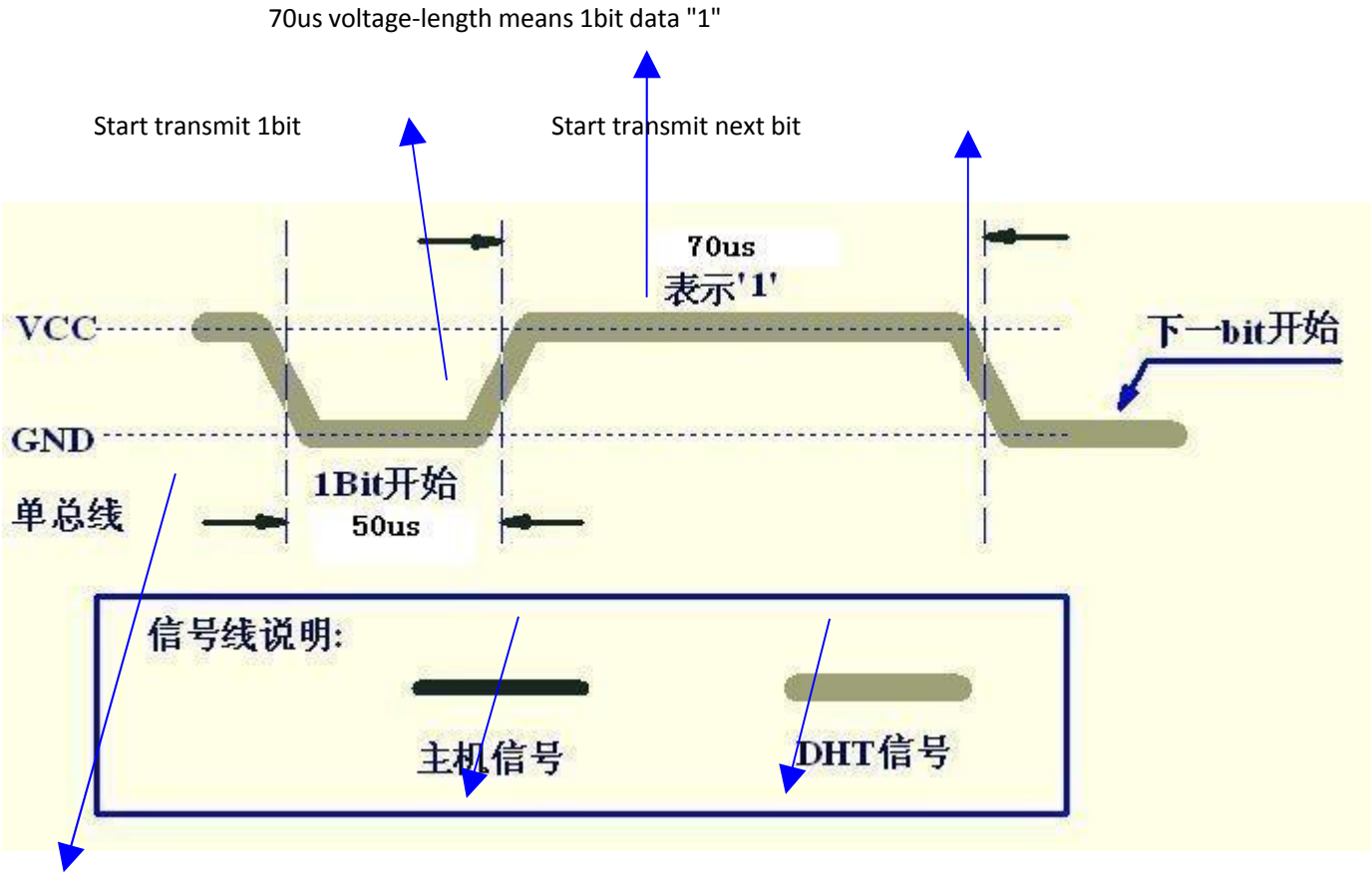
Step 3: DHT22 send data to MCU

When DHT22 is sending data to MCU, every bit's transmission begin with low-voltage-level that last 50us, the following high-voltage-level signal's length decide the bit is "1" or "0".

Check bellow picture for step 3:

Thomas Liu (Business Manager)

Email: thomasliu198518@yahoo.com.cn



Host signal Sesnor's signal

Single-bus signal

If signal from DHT22 is always high-voltage-level, it means DHT22 is not working properly, please check the electrical connection status.

7. Electrical Characteristics:

Item	Condition	Min	Typical	Max	Unit
Power supply	DC	3.3	5	6	V
Current supply	Measuring	1		1.5	mA
	Stand-by	40	Null	50	uA
Collecting period	Second		2		Second

*Collecting period should be : >2 second.

Thomas Liu (Business Manager)

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8. Attentions of application:

(1) Operating and storage conditions

We don't recommend the applying RH-range beyond the range stated in this specification. The DHT22 sensor can recover after working in non-normal operating condition to calibrated status, but will accelerate sensors' aging.

(2) Attentions to chemical materials

Vapor from chemical materials may interfere DHT22's sensitive-elements and debase DHT22's sensitivity.

(3) Disposal when (1) & (2) happens

Step one: Keep the DHT22 sensor at condition of Temperature 50~60Celsius, humidity <10%RH for 2 hours;

Step two: After step one, keep the DHT22 sensor at condition of Temperature 20~30Celsius, humidity >70%RH for 5 hours.

(4) Attention to temperature's affection

Relative humidity strongly depend on temperature, that is why we use temperature compensation technology to ensure accurate measurement of RH. But it's still be much better to keep the sensor at same temperature when sensing.

DHT22 should be mounted at the place as far as possible from parts that may cause change to temperature.

(5) Attentions to light

Long time exposure to strong light and ultraviolet may debase DHT22's performance.

(6) Attentions to connection wires

The connection wires' quality will effect communication's quality and distance, high quality shielding-wire is recommended.

(7) Other attentions

* Welding temperature should be bellow 260Celsius.

* Avoid using the sensor under dew condition.

* Don't use this product in safety or emergency stop devices or any other occasion that failure of DHT22 may cause personal injury.

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KARTU MONITORING BIMBINGAN

MAHASISWA PROGRAM STUDI TEKNIK ELEKTRO
FAKULTAS TEKNIK
UNIVERSITAS MUHAMMADIYAH PAREPARE

PROPOSAL

ıgiswa	: MUH.ISMAIL MUSTAPA	Pembimbing I : Muhammad Basri, ST., MT.
	: 218 180 010	Pembimbing II : Alauddin Y., ST., M.Kom.
Skripsi	: STUDI EKSPERIMENTAL PERFORMANSI SENSOR SUHU PADA SISTEM PENGUKURAN TEMPRATURE	

ARAHAN PEMBIMBING I	HARI/TGL & PARAF PEMBIMBING	ARAHAN PEMBIMBING II	HARI/TGL & PARAF PEMBIMBING
tasi 1		Konsultasi 1 model tabel performance !	
tasi 2		Konsultasi 2 ~~Jenis sens~~ alat pembanding !	
ltasi 3		Konsultasi 3 Variabel 2 pengukuran x !	
ltasi 4		Konsultasi 4	
ltasi 5 ee proposal		Konsultasi 5 Acc	

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Lanjutan ...

ARAHAN PEMBIMBING I	HARI/TGL & PARAF PEMBIMBING	ARAHAN PEMBIMBING II	HARI/TGL & PARAF PEMBIMBIN
Konsultasi 6		Konsultasi 6	
Konsultasi 7		Konsultasi 7	
Konsultasi 8		Konsultasi 8	
Konsultasi 9		Konsultasi 9	
Konsultasi 10		Konsultasi 10	

Parepare, 2025

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Asrul, ST., MT
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HASIL

ahasiswa : MUH. ISMAIL MUSTAPA	Pembimbing I : Muhammad Basri, ST., MT.
M : 218180010	Pembimbing II : Alauddin Y., ST., M.Kom.
dul Skripsi : STUDI EKSPERIMENTAL PERFORMANSI SENSOR SUHU PADA SISTEM PENGUKURAN TEMPERATUR	

ARAHAN PEMBIMBING I	HARI/TGL & PARAF PEMBIMBING	ARAHAN PEMBIMBING II	HARI/TGL & PARAF PEMBIMBING
nsultasi 1		Konsultasi 1 - Abstrak - Teori warna u/ grafik	30/4/2024
nsultasi 2		Konsultasi 2 - Lengkapi Bibliografi	30/4/2024
nsultasi 3		Konsultasi 3 Koreksi Abstrak Kata kunci	3/5/24
nsultasi 4		Konsultasi 4 —	4/5/24
nsultasi 5 ACC pelaksanaan Hasil		Konsultasi 5	2/5/2024

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ARAHAN PEMBIMBING I	HARI/TGL & PARAF PEMBIMBING	ARAHAN PEMBIMBING II	HARI/T PAR PEMBI
Konsultasi 6		Konsultasi 6	
Konsultasi 7		Konsultasi 7	
Konsultasi 8		Konsultasi 8	
Konsultasi 9		Konsultasi 9	
Konsultasi 10		Konsultasi 10	

Parepare, 30 April 2025

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Ashadi Amir ST., MT.
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l Skripsi : STUDI EKSPERIMENTAL PERFORMANSI SENSOR SUHU PADA SISTEM PENGUKURAN TEMPERATUR	

ARAHAN PEMBIMBING I	HARI/TGL & PARAF PEMBIMBING	ARAHAN PEMBIMBING II	HARI/TGL & PARAF PEMBIMBING
ltasi 1		Konsultasi 1	
ltasi 2		Konsultasi 2	
ltasi 3		Konsultasi 3	
ltasi 4		Konsultasi 4	
ltasi 5		Konsultasi 5	

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Lanjutan ...

ARAHAN PEMBIMBING I	HARI/TGL & PARAF PEMBIMBING	ARAHAN PEMBIMBING II	HARI/TGL PARAF PEMBIMBI
Konsultasi 6		Konsultasi 6	
Konsultasi 7		Konsultasi 7	
Konsultasi 8		Konsultasi 8	
Konsultasi 9		Konsultasi 9	
Konsultasi 10		Konsultasi 10	

Parepare, 30 MEI 2025

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