External peripheral circuits for microprocessor systems – examples (useful for projects...)

Lecture 9

Semester 20L – Summer 2020

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Important remark

This material is intended to be used by the students during the Microprocessor Systems course for educational purposes only. The course is conducted in the Faculty of Electronics, Warsaw University of Technology.

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Project information

- **It is about time to start preparing your projects!**

- Projects **should be consulted** – via mail or during consultation hours

- Due to the fact that some projects require information about power saving modes and ADC/DACs **the deadline for projects is postponed by two weeks**

- **The new deadline for projects is Friday, 7th June. Projects sent after this deadline WILL NOT BE CHECKED**

External peripheral circuits examples

- Presented circuits will be divided into following categories:
- Communication
- Digital signal processing
- Analog signal processing
- Sensors
- Many more available in literature and on the Internet
- Presented examples may be found useful during project design and preparation

Communication – USB bus and protection circuits

- Circuits used to implement USB communication in microprocessor systems were shown in previous lecture.
- It is important to remember about protecting system against external actions, like electrostatic discharge, or electromagnetic interference.
- There are several ways to make USB bus invulnerable, or at least less vulnerable to electrostatic discharge:
- STF202 by Semtech, or simply Zener diodes

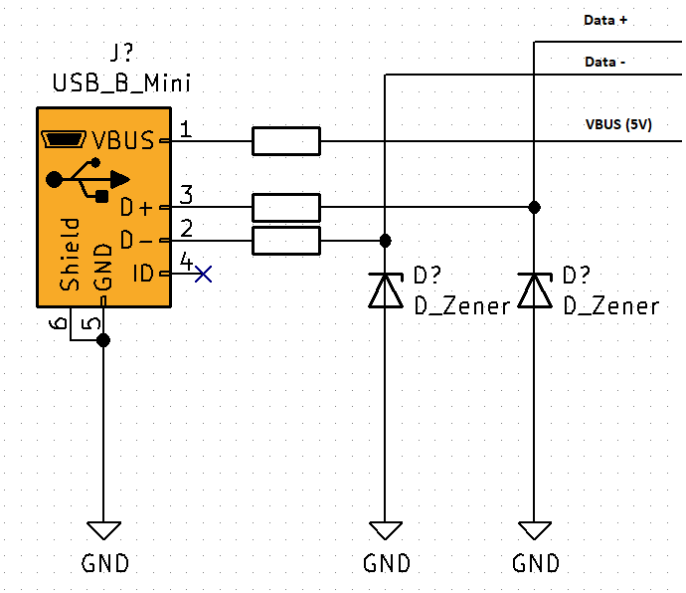


Figure 1 - STF201 Functional Circuit Diagram

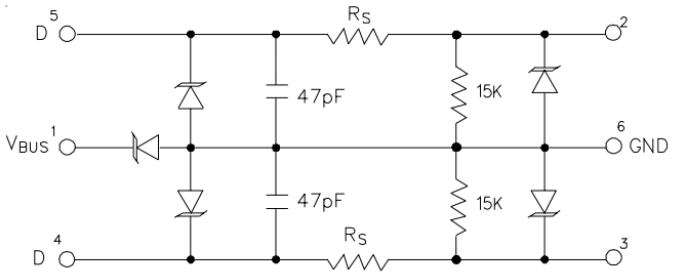


Figure 2 - STF201 Connection Diagram

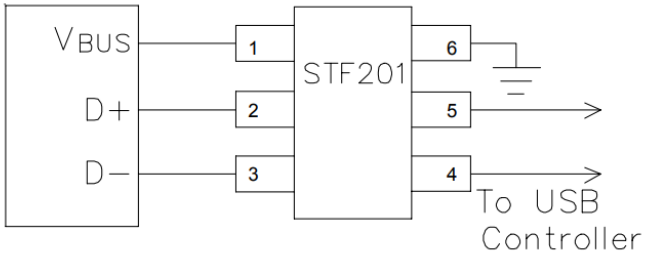


Image source: Semtech datasheet

Communication – WiFi modules

- Many modern applications require to be connected to the Internet or LAN network. One of methods is wireless connection, using WiFi.
- There are many useful modules, available as standalone parts or PCB mini devices that may be embedded into bigger applications, for example ESP32, ESP8266 or WiFi232
- It is particularly hot topic because of IoT applications and it's huge market
  - It is currently worth around 250 billion USD
  - It is expected to double its value by 2021

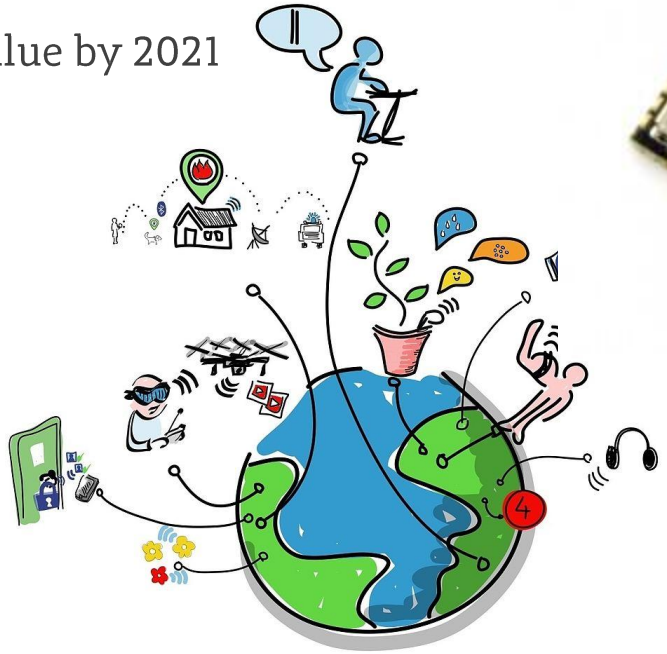


Image source: https://botland.com.pl/pl/moduly-wifi/7655-uklad-wifi-bluetooth-ble-esp-wroom-32-smd.html
http://en.wikipedia.org

Communication – 433 MHz transmitters, receivers

- It is not the purpose of this course to show how to design radio transmitters and receivers.
- It is important to show how to use commercially available modules in custom applications.

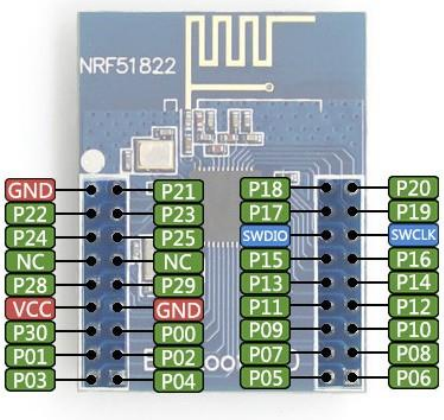
- There are many commercially available modules that offer wireless communication ability for a microprocessor system

- Such modules can be very simple, yet powerful

Image source: https://botland.com.pl/pl/moduly-radiowe/3191-modul-radiowy-nadajnik-fs100a-odbiornik-433-mhz.html

Communication – Bluetooth modules

- Bluetooth modules are also widely available and popular
- In most cases they are using simple serial communication protocols, like SPI or SWD
- They can offer Bluetooth functionallity, but also they may be used as GPIO expanders
- CC2540 – 8051 with Bluetooth by TI



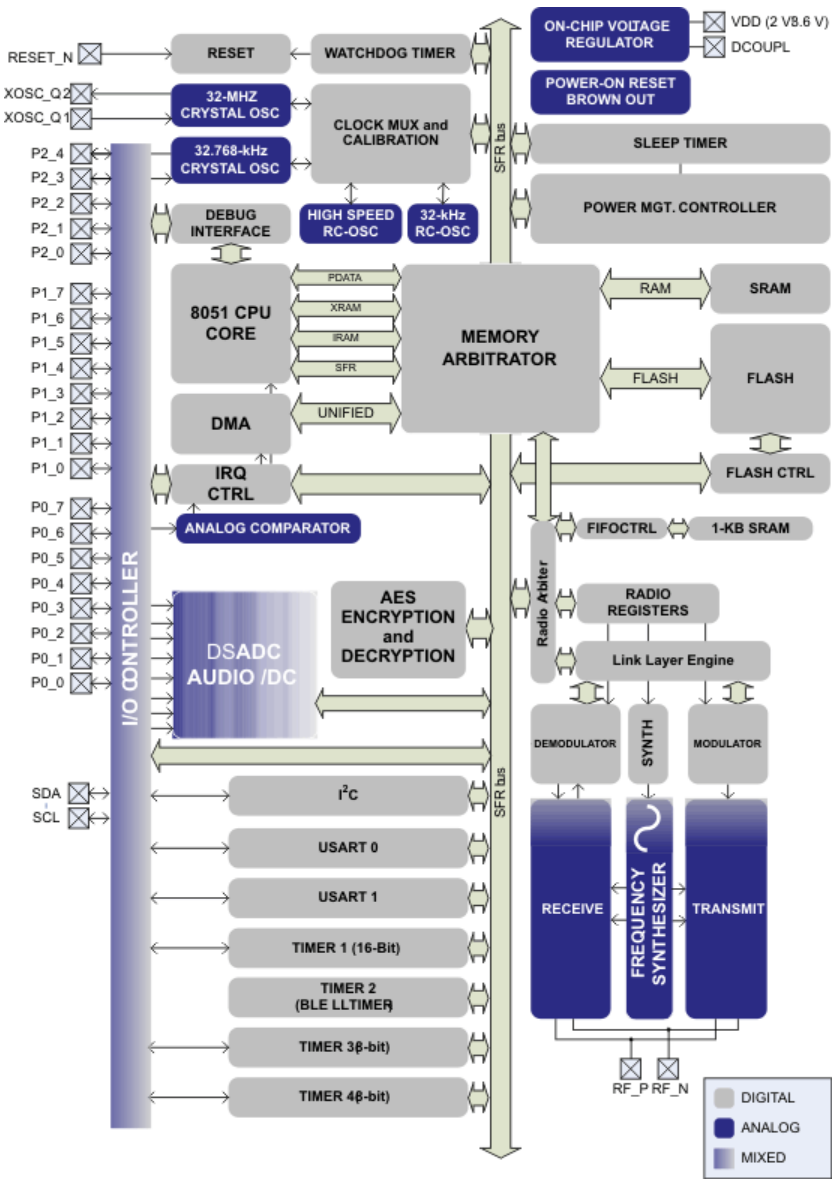


Image source: https://botland.com.pl/pl/moduly-bluetooth/4505-modul-bluetooth-low-energy-ble-40-nrf51822.html

Processing digital signals – accelerometer example

- Most of modern accelerometer chips are manufactured as MEMS – micro electro mechanical systems
- They are manufactured using microelectronic fabrication techniques that create mechanical structures in silicon.

- Such mechanical structure, etched in silicon, can be sensitive to tilt, to movement, to pressure, etc.

- Integrated digital driver translates signals from mechanical structure to digital signals and then transmits them using proper standards, like SPI or I2C.

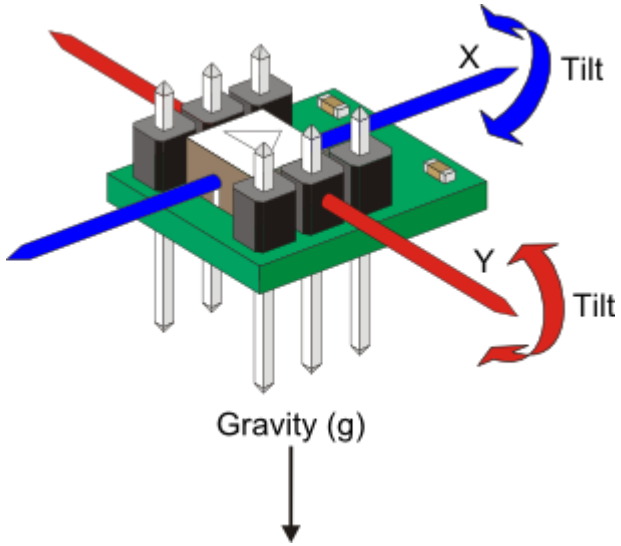


Image source: http://www.ic0nstrux.com/Memsic-2125-Dual-axis-Accelerometer#.XL7VmLvVKUk

Processing digital signals – accelerometer example

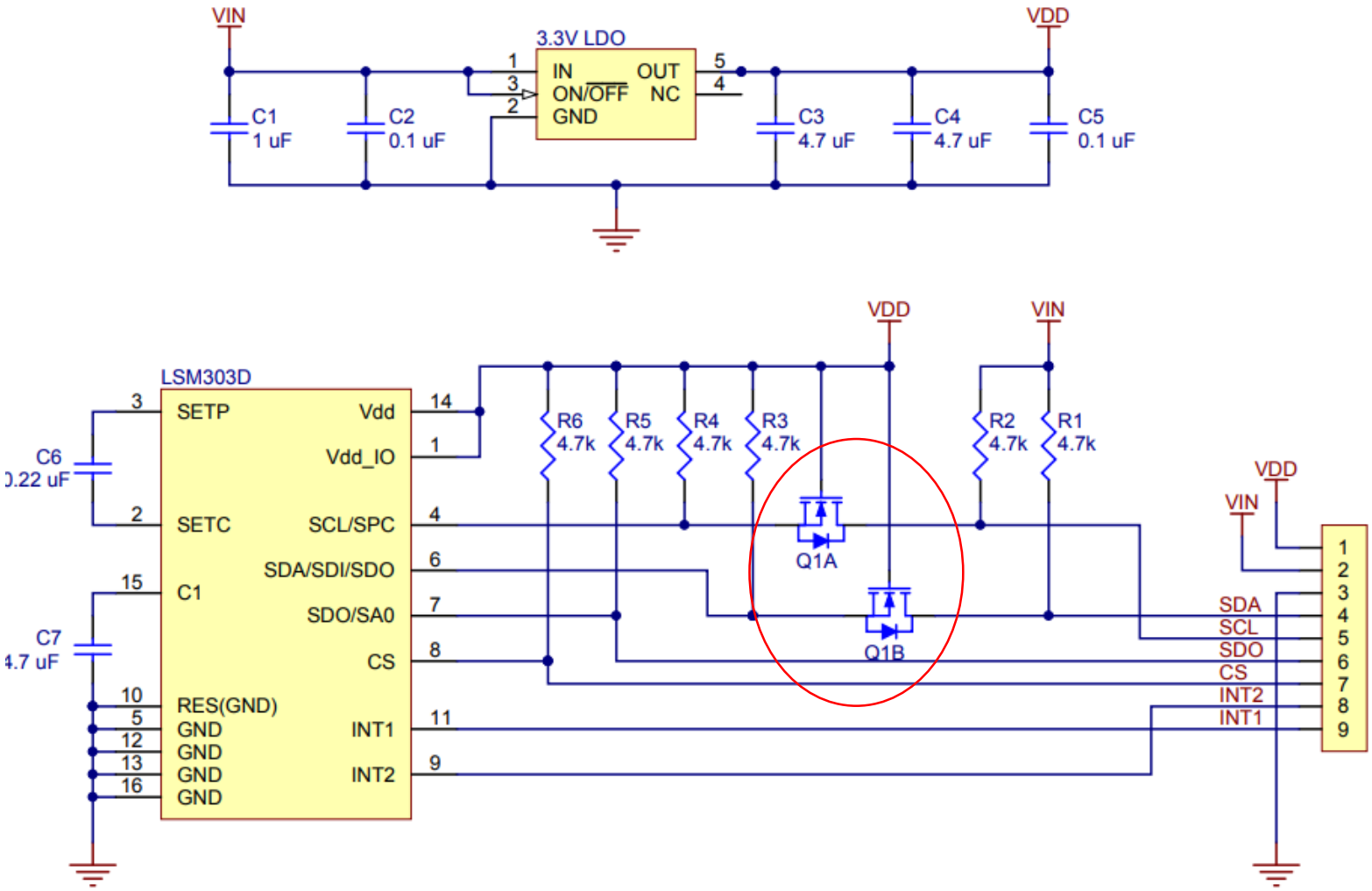


Image source: http://www.kamami.pl

Processing digital signals – stepper motor driver

- A stepper motor is a type of electric motor that is driven by current pulses applied to its windings. This causes that it is not rotating all the time, but instead it turns in steps
- Unlike typical brushed motor it is possible to precisely control the step angle and thus to use stepper motors in high precision applications, like:
  - CNC machining
  - High end audio potentiometers
  - Printers
  - Hard drives

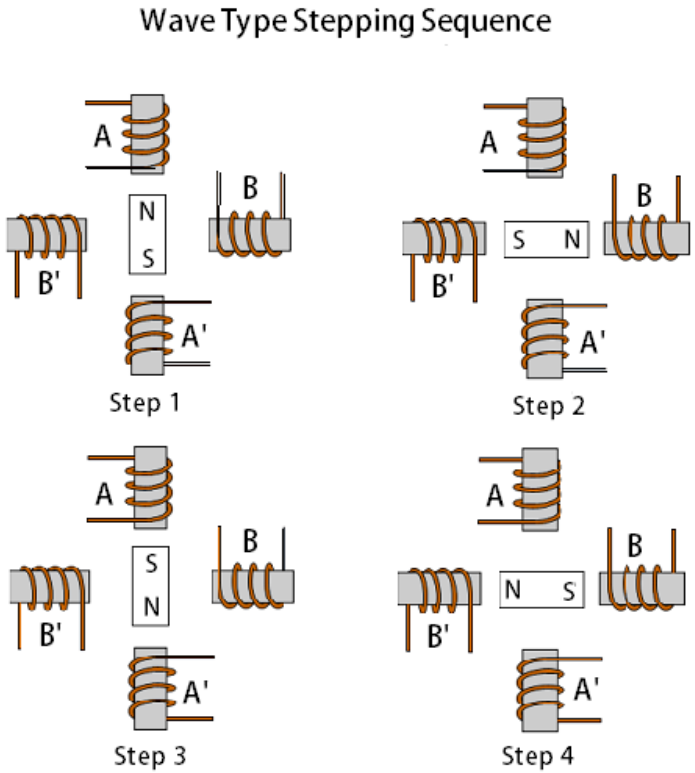


Image source: https://embedjournal.com/stepper-motors-introduction-and-working-principle/

Processing digital signals – stepper motor driver

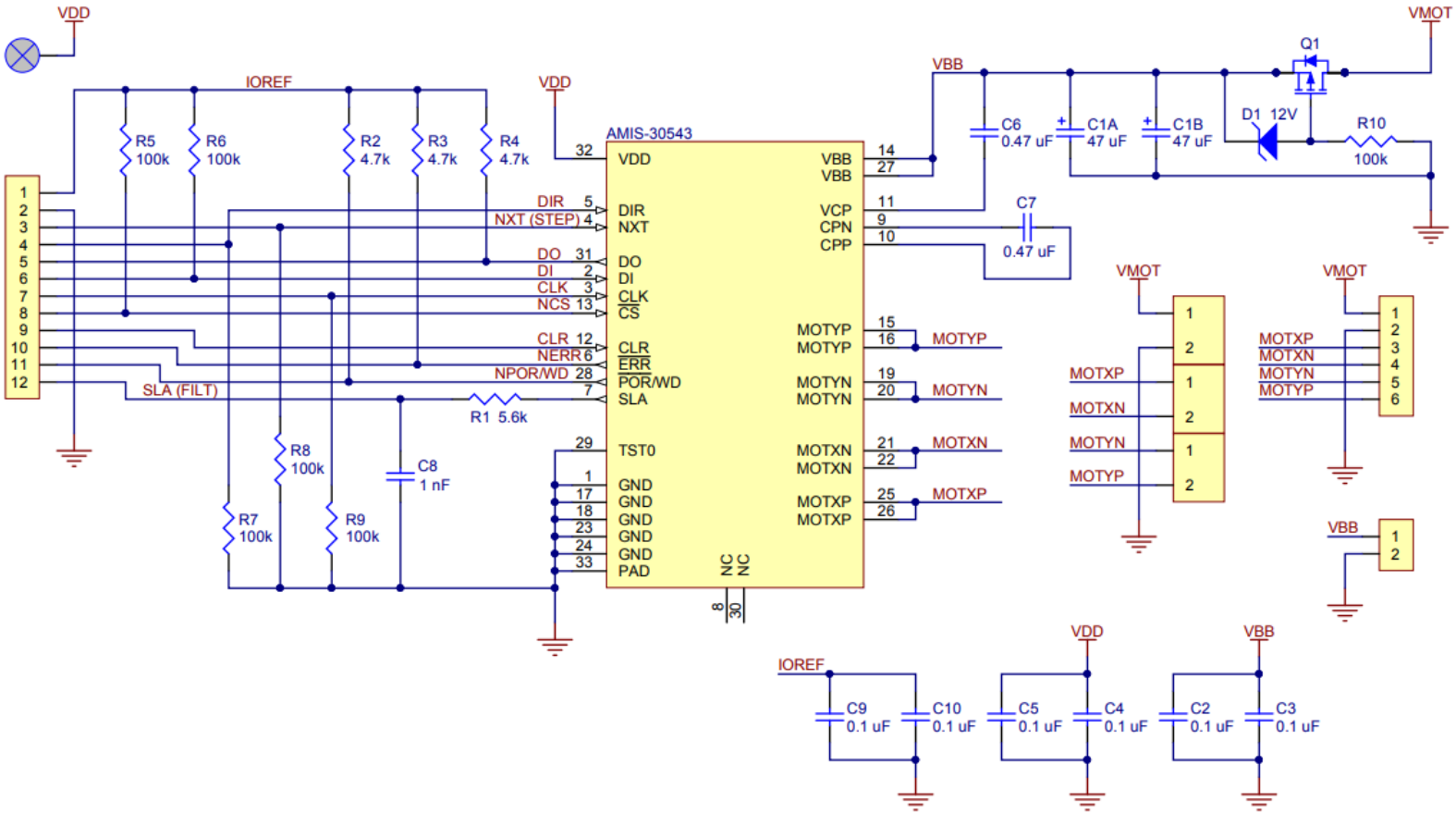


Image source: https://www.pololu.com/file/0J870/amis-30543-carrier-schematic-diagram.pdf

Processing digital signals – GPIO expanders

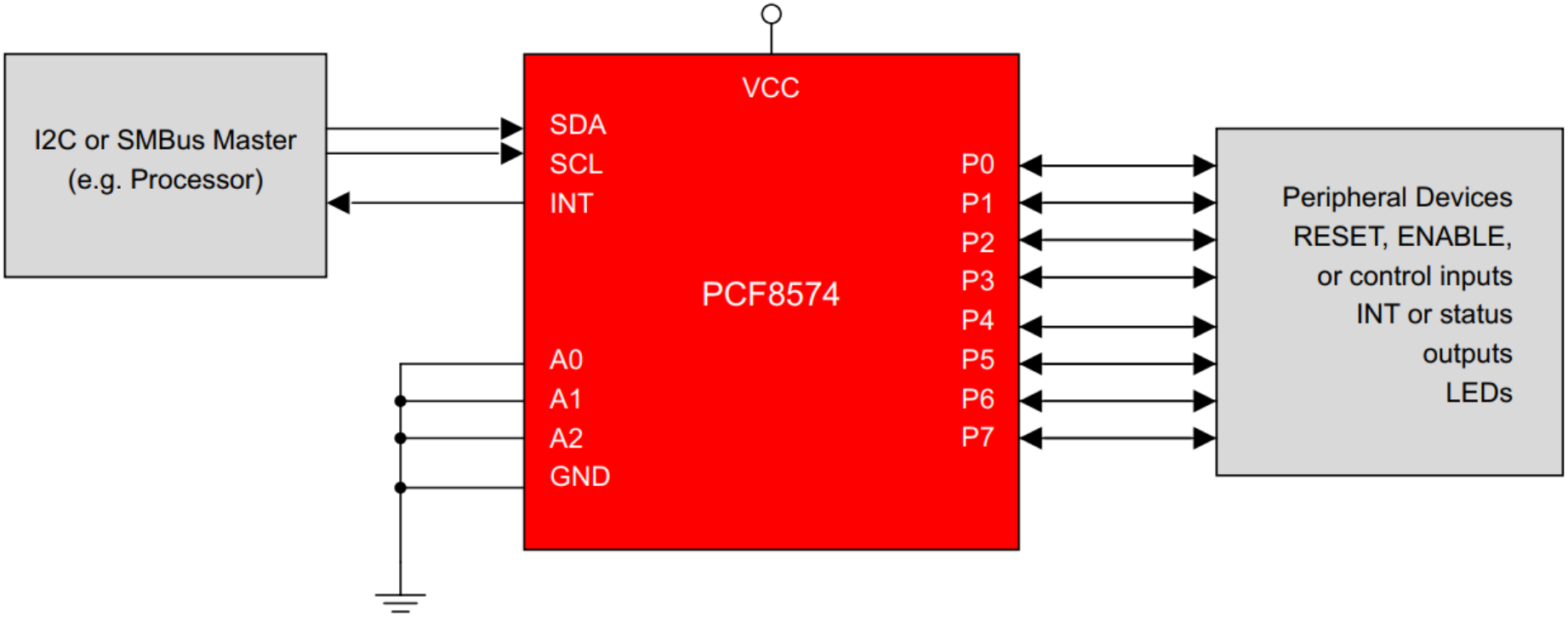


Image source: https://www.ti.com

9.2 Typical Application

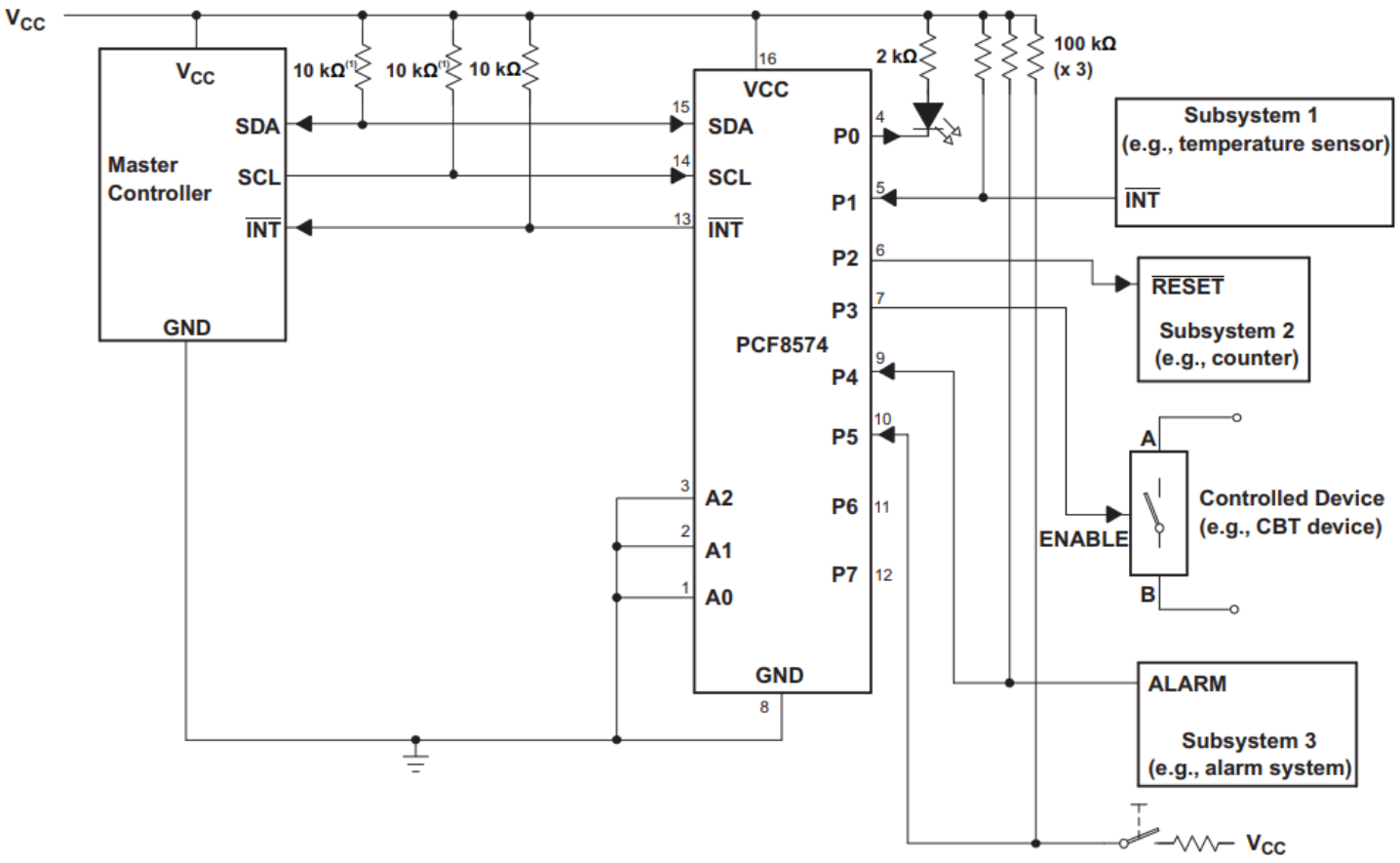


Image source: https://www.ti.com

Processing digital signals – RTC (Real Time Clock) circuits

- RTC (Real Time Clock) is a digital circuit, usually a part of microcontroller (internal peripheral) or standalone chip that is used as an ordinary clock and calendar. It can keep track of timing even if the microcontroller is reprogrammed, or if the system is cut off from power source (if it has extra power supply, like battery)

Typical Operating Circuit

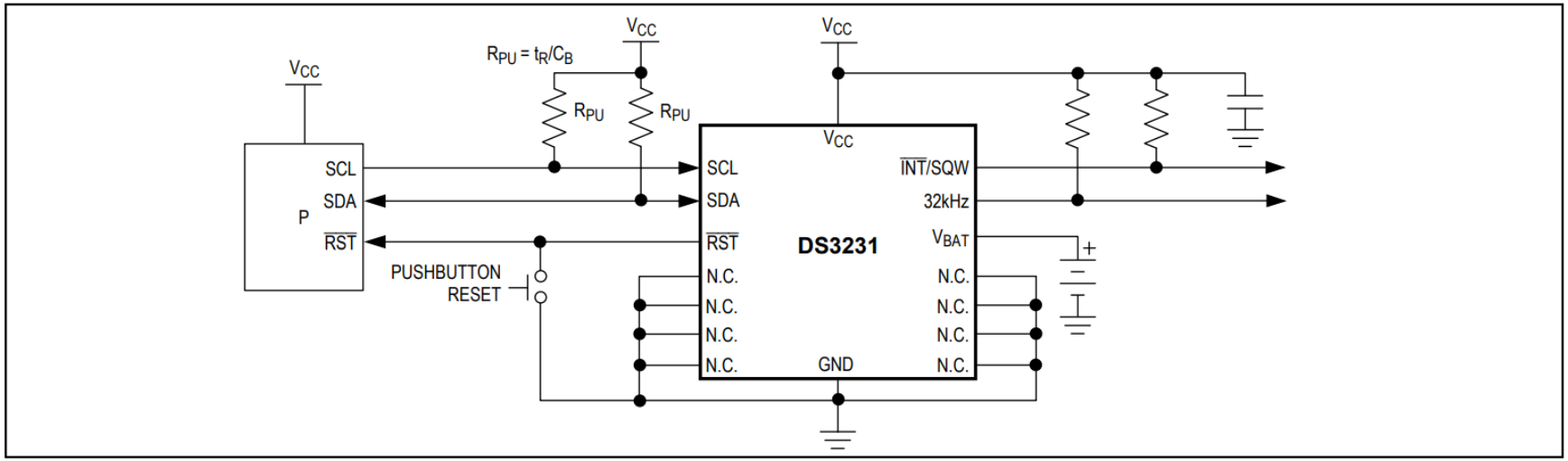


Image source: https://datasheets.maximintegrated.com, https://learn.adafruit.com/ds1307-real-time-clock-breakout-board-kit/what-is-an-rtc

Processing digital signals – RTC (Real Time Clock) circuits

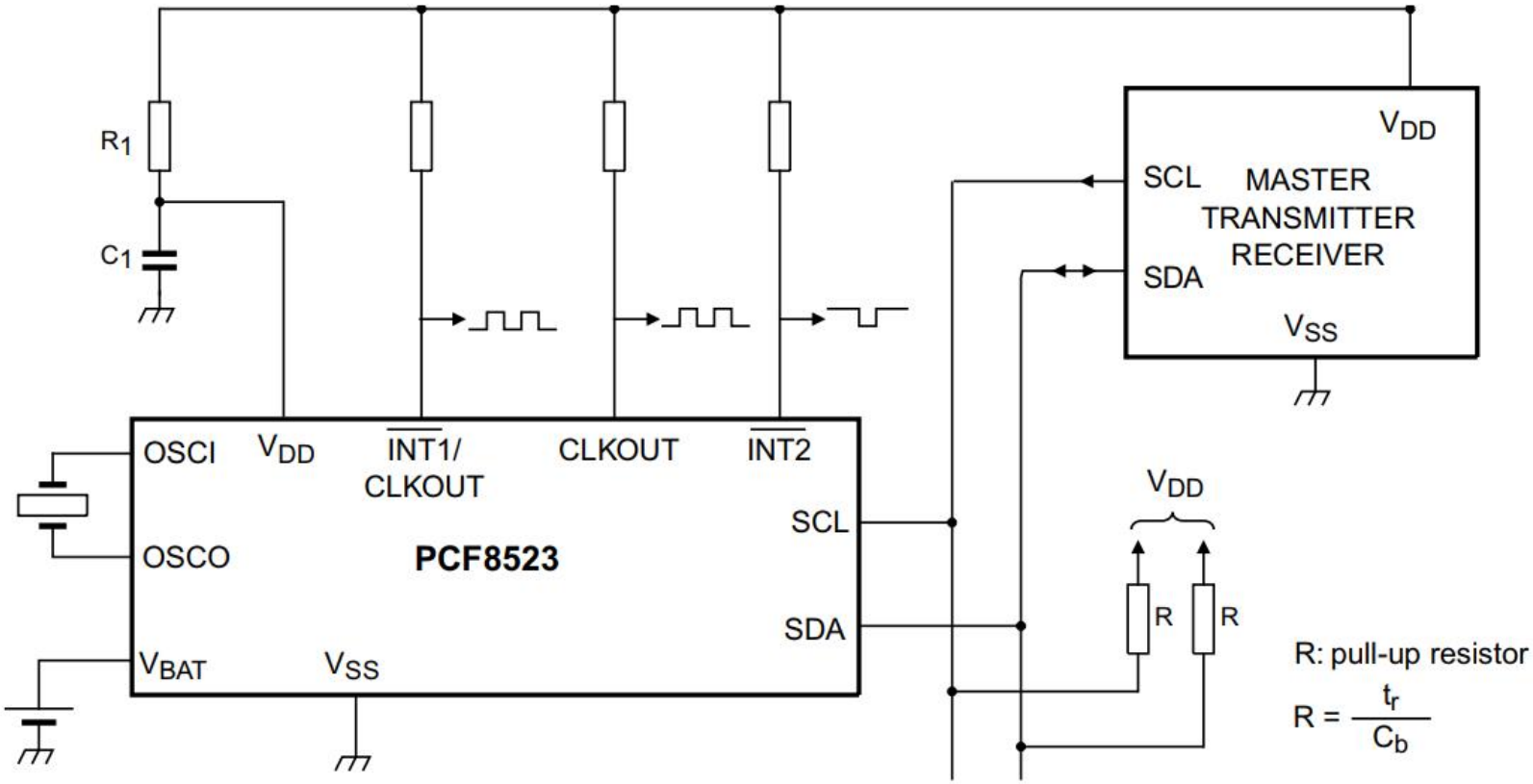


Image source: https://www.nxp.com

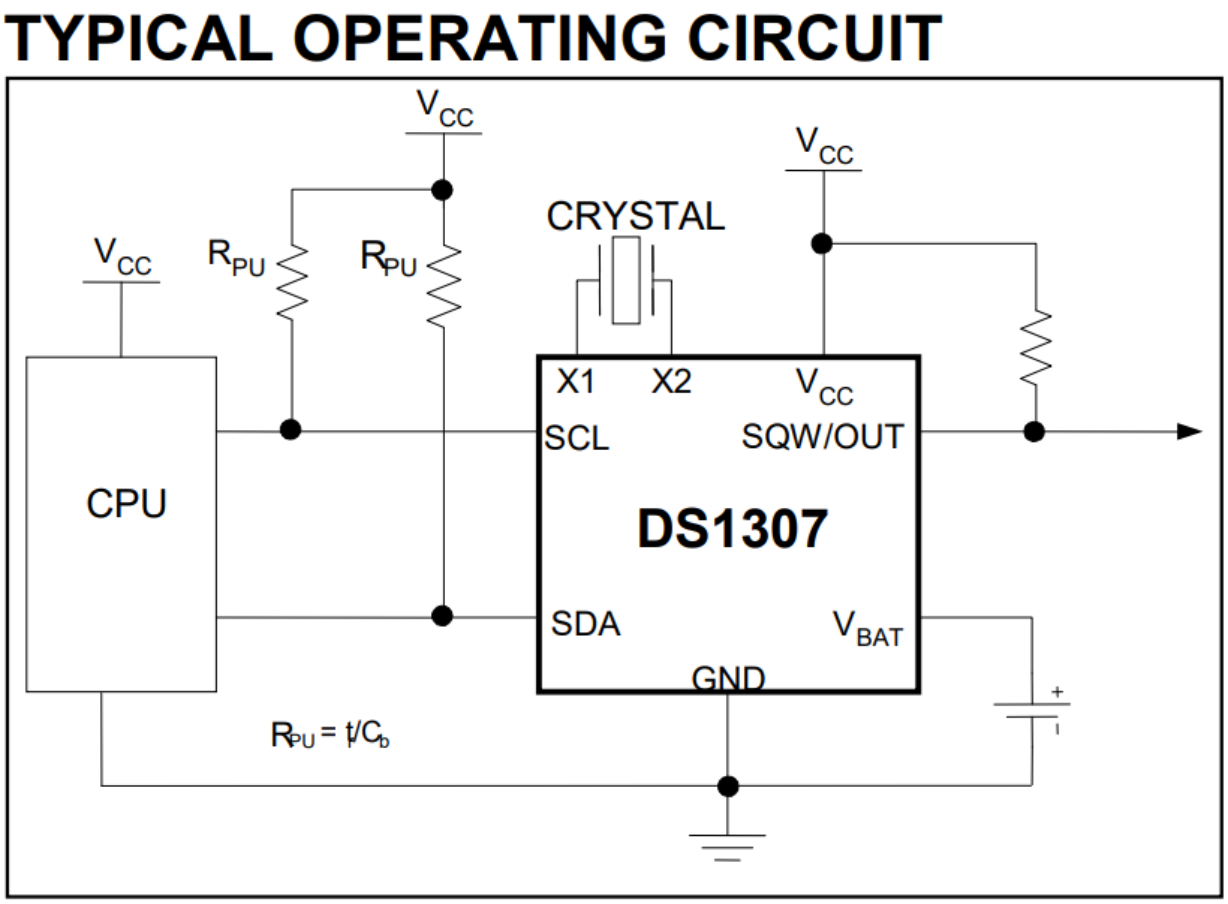


Image source: https://www.nxp.com

Processing analog signals – DDS – Direct Digital Synthesis

- Direct Digital Synthesis is a way to generate arbitrary waveform signals, using a single reference clock signal. DDS synthesizers are used as signal generators, local oscillators, mixers, modulators and as VCO in PLLs.

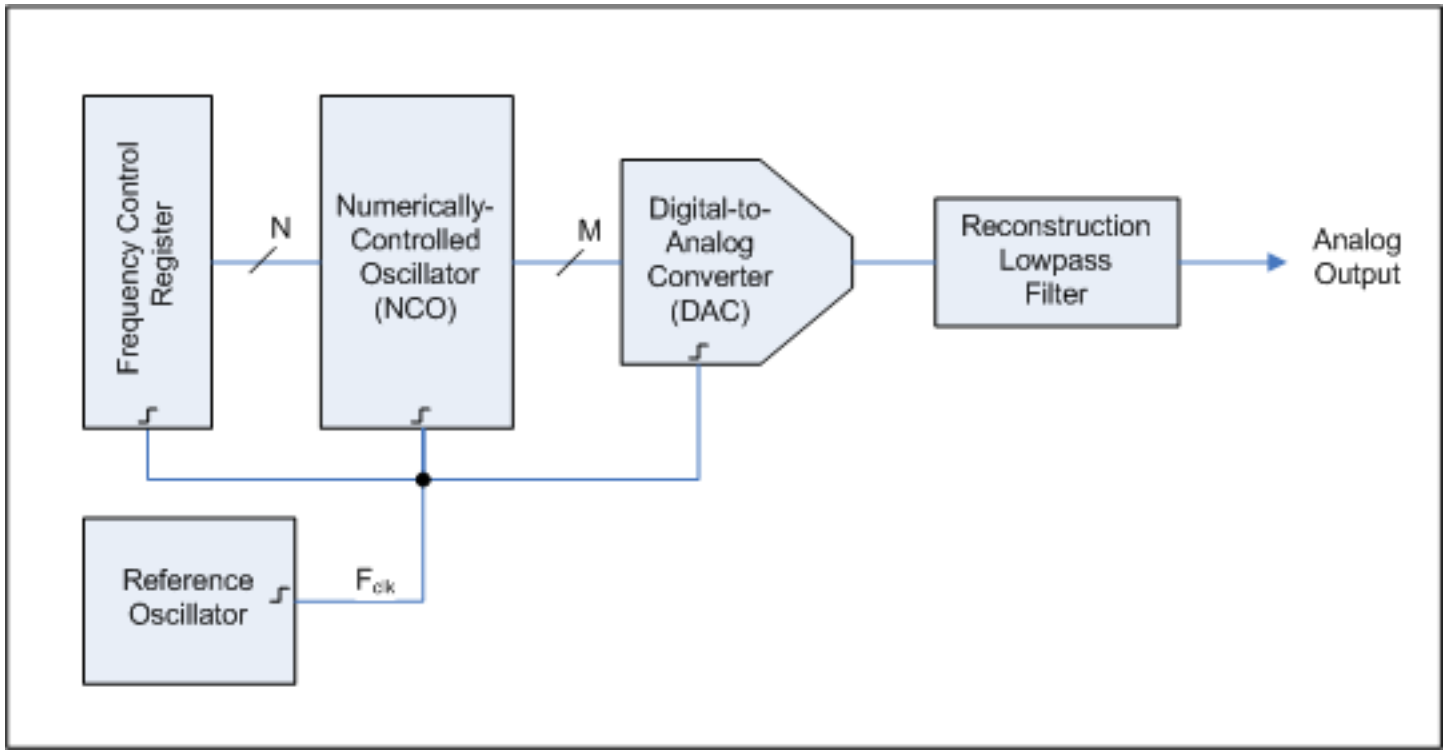


Image source: https://en.wikipedia.org

Processing analog signals – DDS – Direct Digital Synthesis

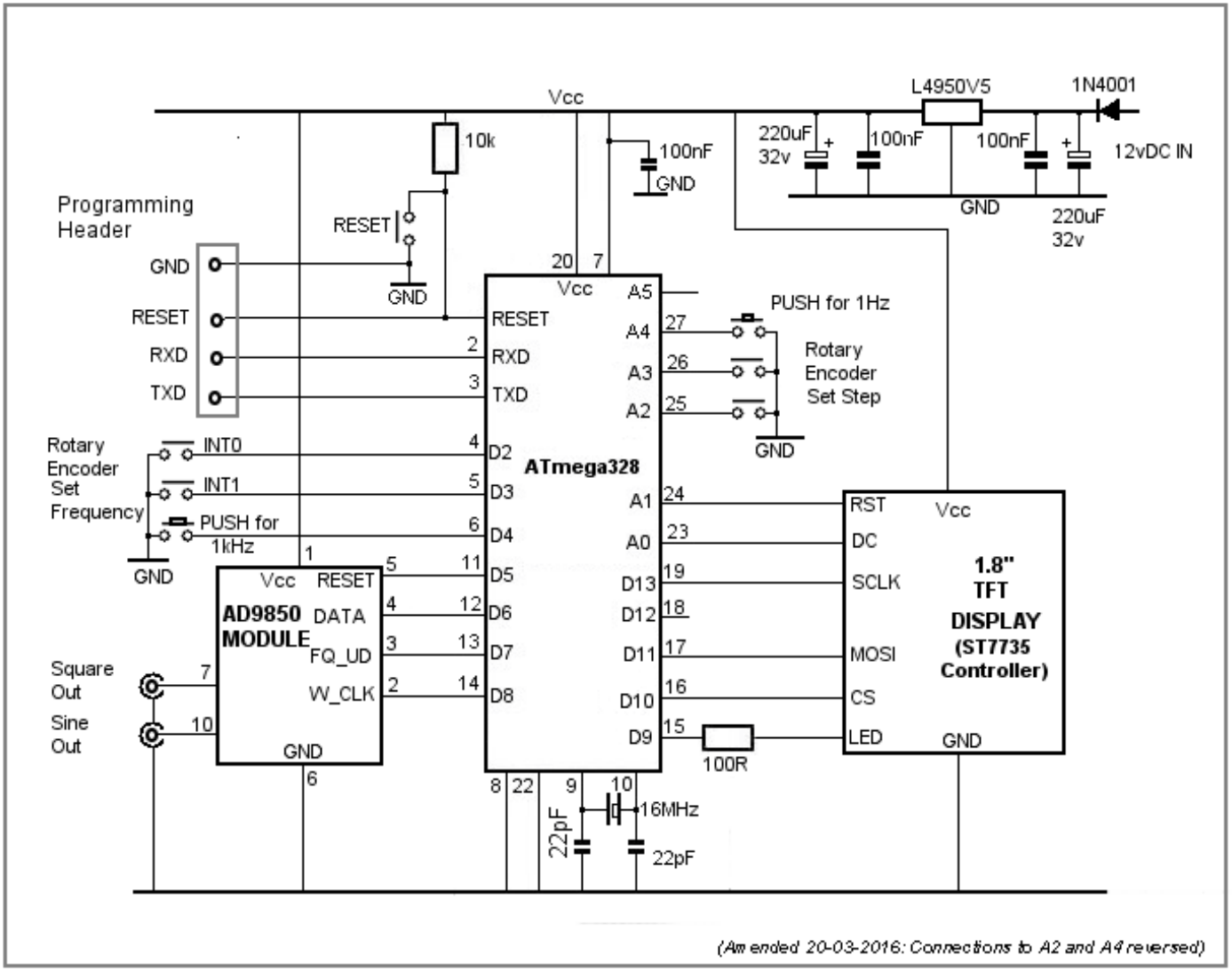


Image source: http://vwlowen.co.uk/arduino/AD9850-waveform-generator/AD9850-waveform-generator.htm

Processing analog signals – DDS – Direct Digital Synthesis

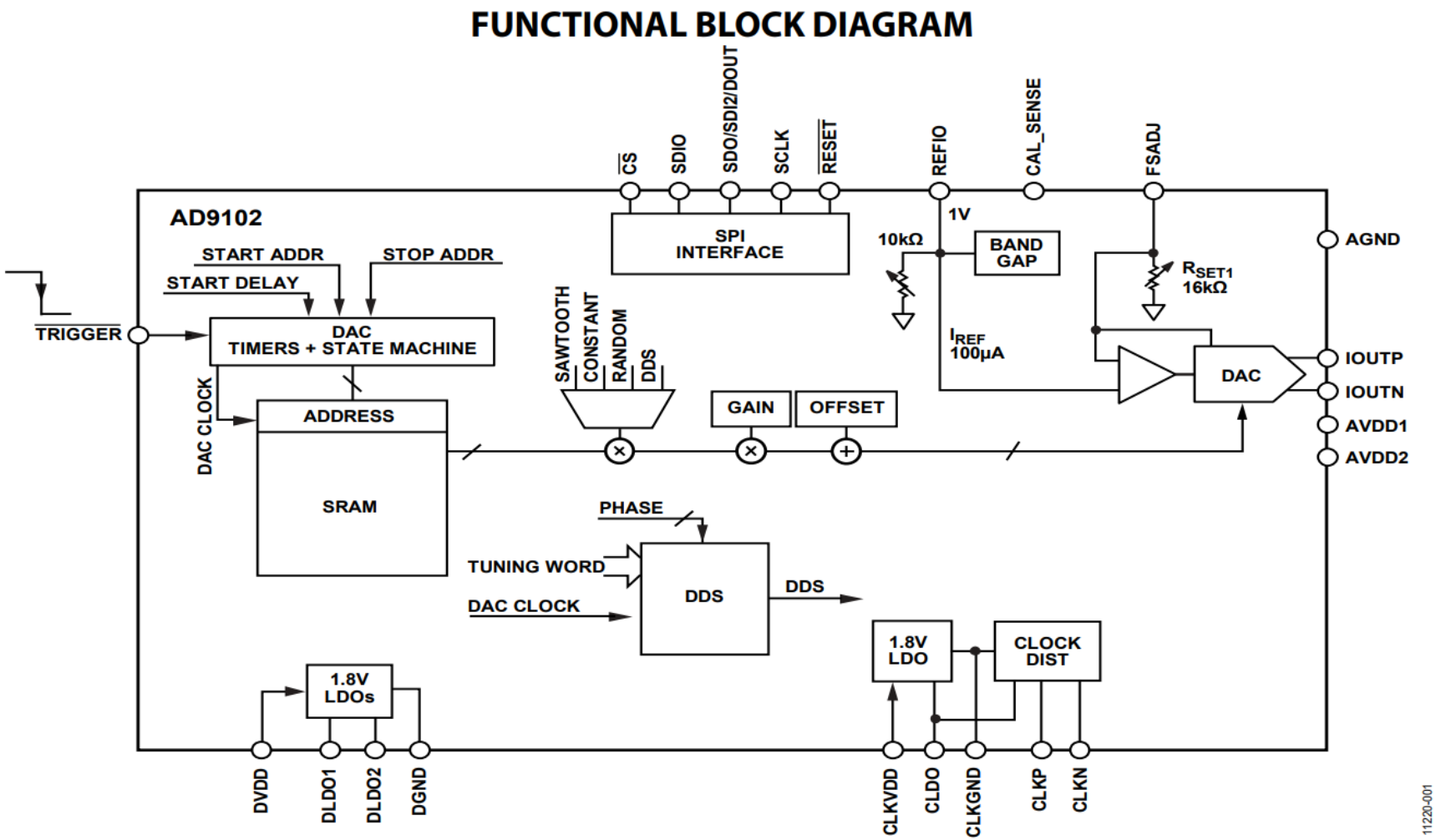


Figure 1.

Image source: https://www.analog.com

Processing analog signals – RF power detector

- In RF systems it is often (almost always) required to control power of analog high frequency signals. This is done using many different types of power detectors. In principle a power detector is converting RF signal power to DC voltage than can be then measured using ADC or voltmeter.

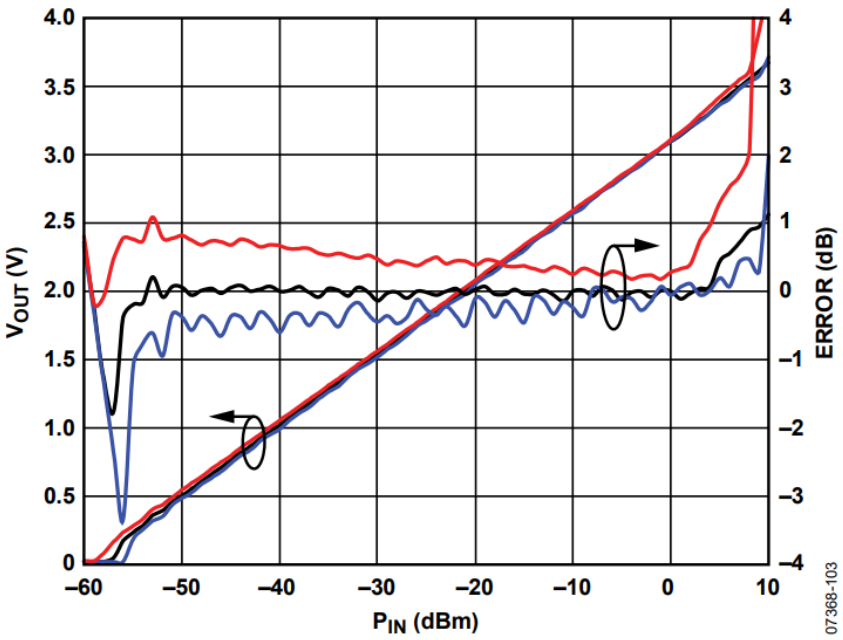


Figure 3. V_{OUT} and Log Conformance vs. Input Power and Temperature at 100 MHz

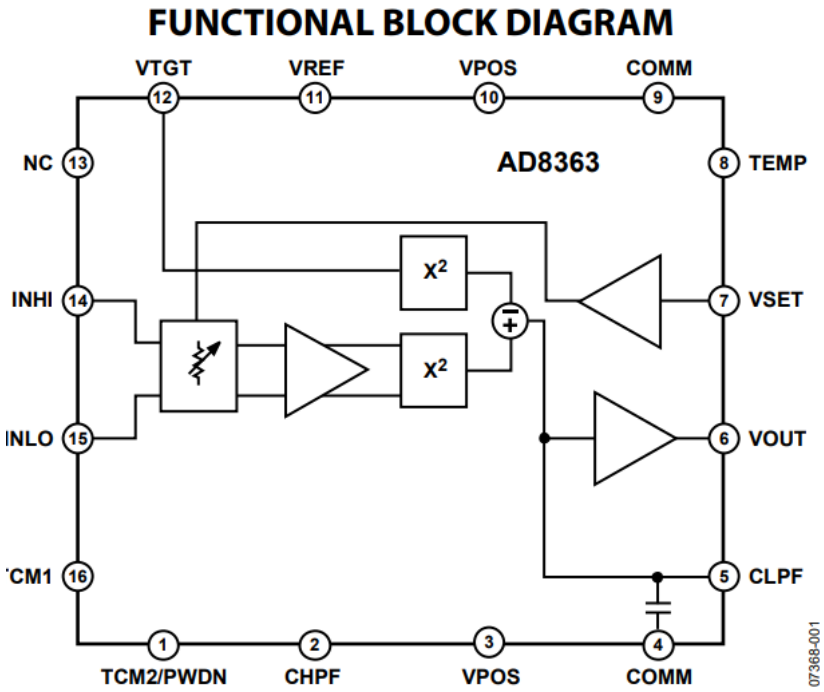


Figure 1. AD8363 Block Diagram

Image source: https://www.analog.com

Processing analog signals – RF power detector

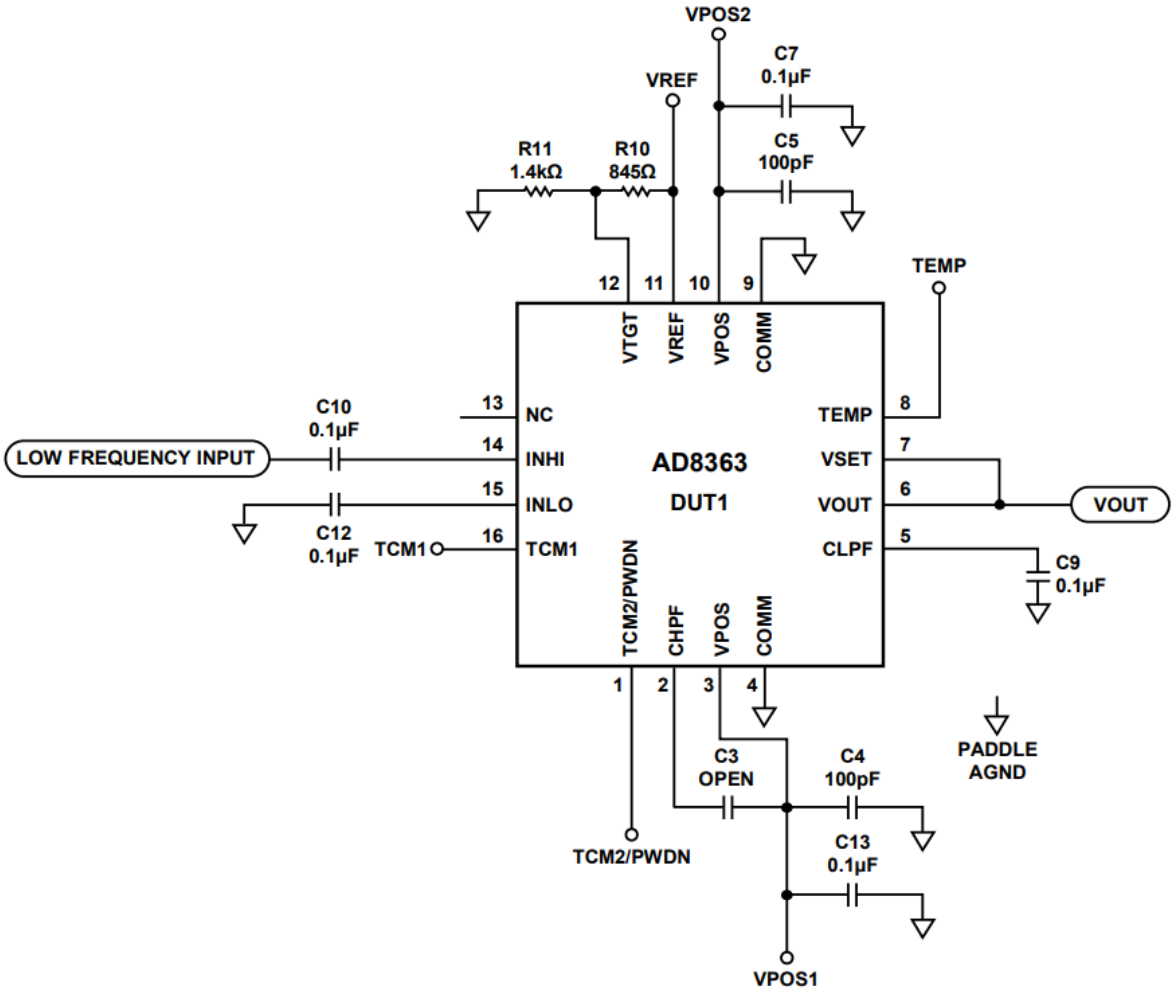


Image source: https://www.analog.com

Sensors – thermocouple driver

- Thermocouple is a thermal sensor capable of measuring very high temperatures, often exceeding 600 degrees. It consists of two separate electrodes, made of two different types of conductor, like copper and iron. Among these electrodes the Seebeck effect occurs – there is a voltage across the electrodes, proportional to temperature.

- Thermocouples require special driver circuits. They can be made of operational amplifiers or special chips, like MAX31855 from Maxim Integrated (voltage amplifier and ADC)

Typical Application Circuit

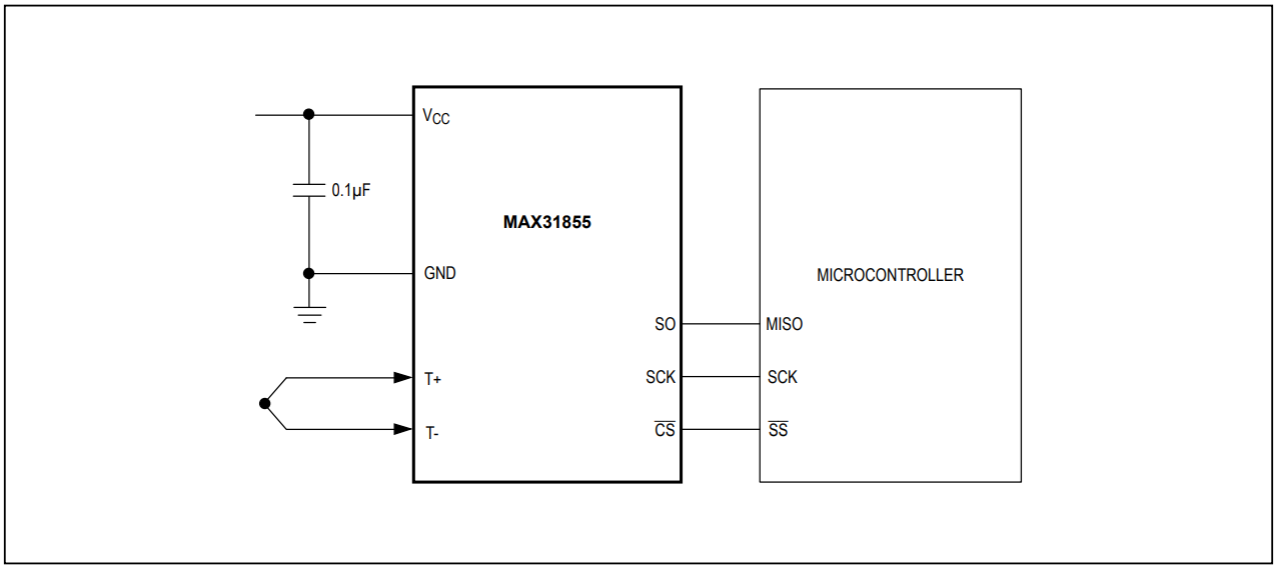


Image source: https://datasheets.maximintegrated.com

Sensors – PT100 driver

- In some applications it is not needed to measure very high temperatures, but instead it is required to measure temperature with very high resolution and precision. In these applications resistive thermal sensors (RTDs) should be used. One of most popular RTDs are platinum sensors, like PT100 or PT1000.

- PT100 has 100 Ohm resistance in 0 degrees Celsius.
- To drive resistive thermal sensors a current source or special driver (MAX31865 for instance) has to be used.

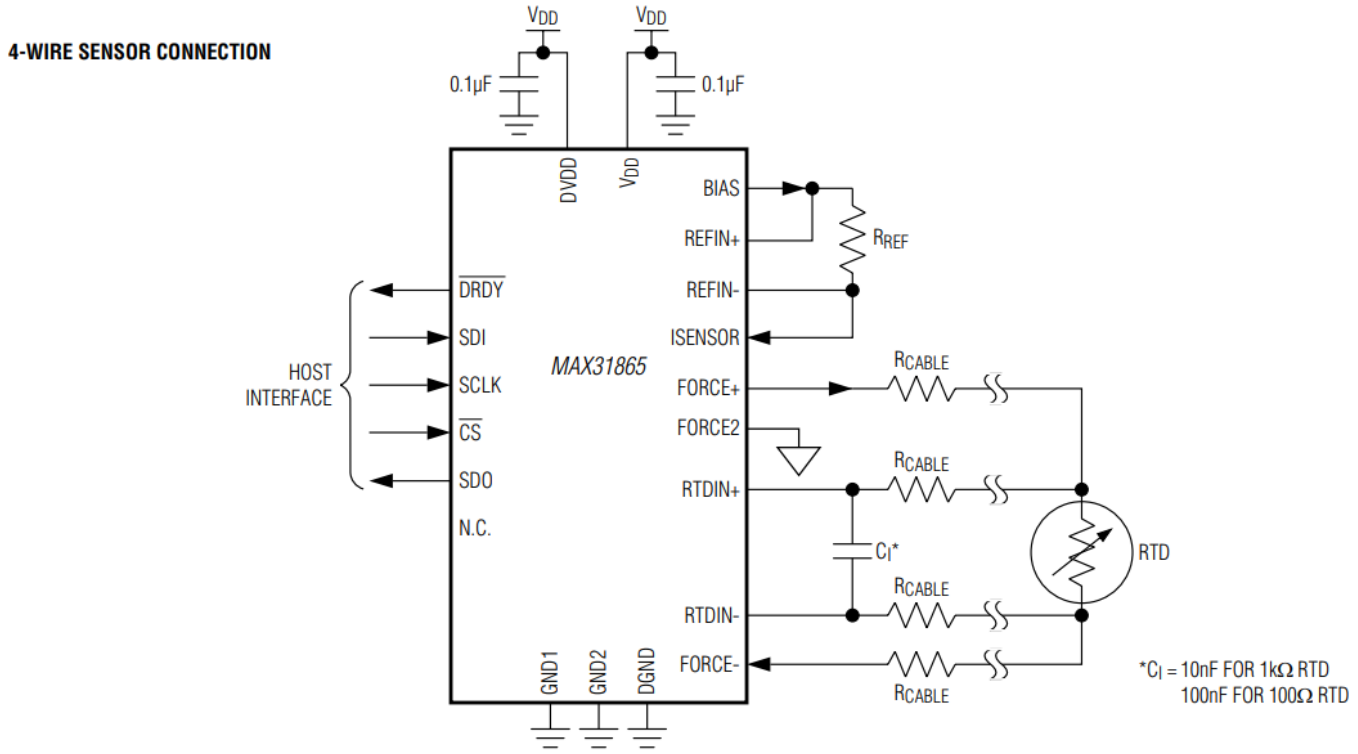


Image source: https://datasheets.maximintegrated.com

Sensors – DS18B20

- There are also lots of digital temperature sensors. One of the most popular (but not the best) is DS18B20. It is a digital thermometer that provides 9 to 12-bit temperature measurements. It communicates using 1-wire bus, that requires only 2 wires – one signal/power wire and ground/return wire

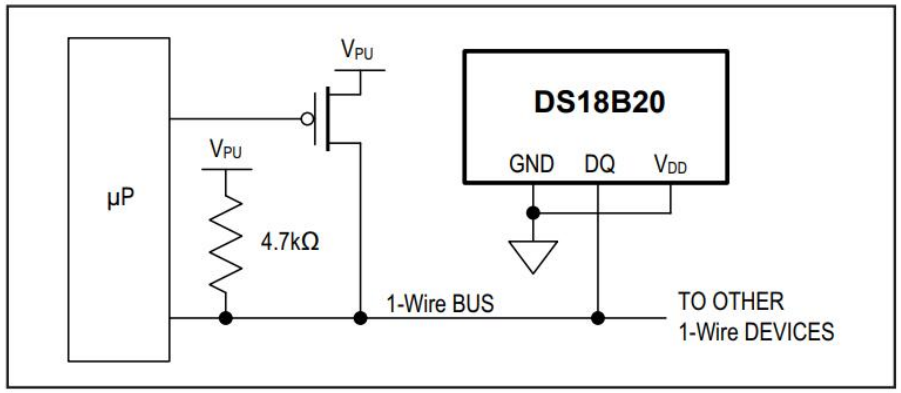


Figure 6. Supplying the Parasite-Powered DS18B20 During Temperature Conversions

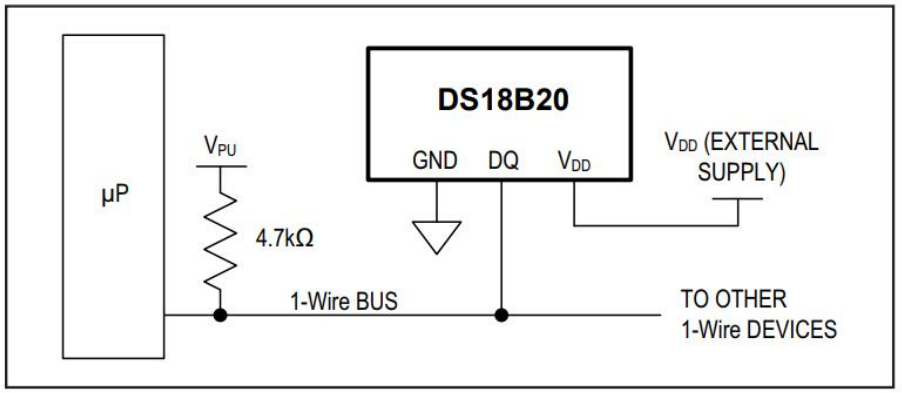


Figure 7. Powering the DS18B20 with an External Supply

Image source: https://datasheets.maximintegrated.com

Sensors – HDC1000 – temperature and humidity

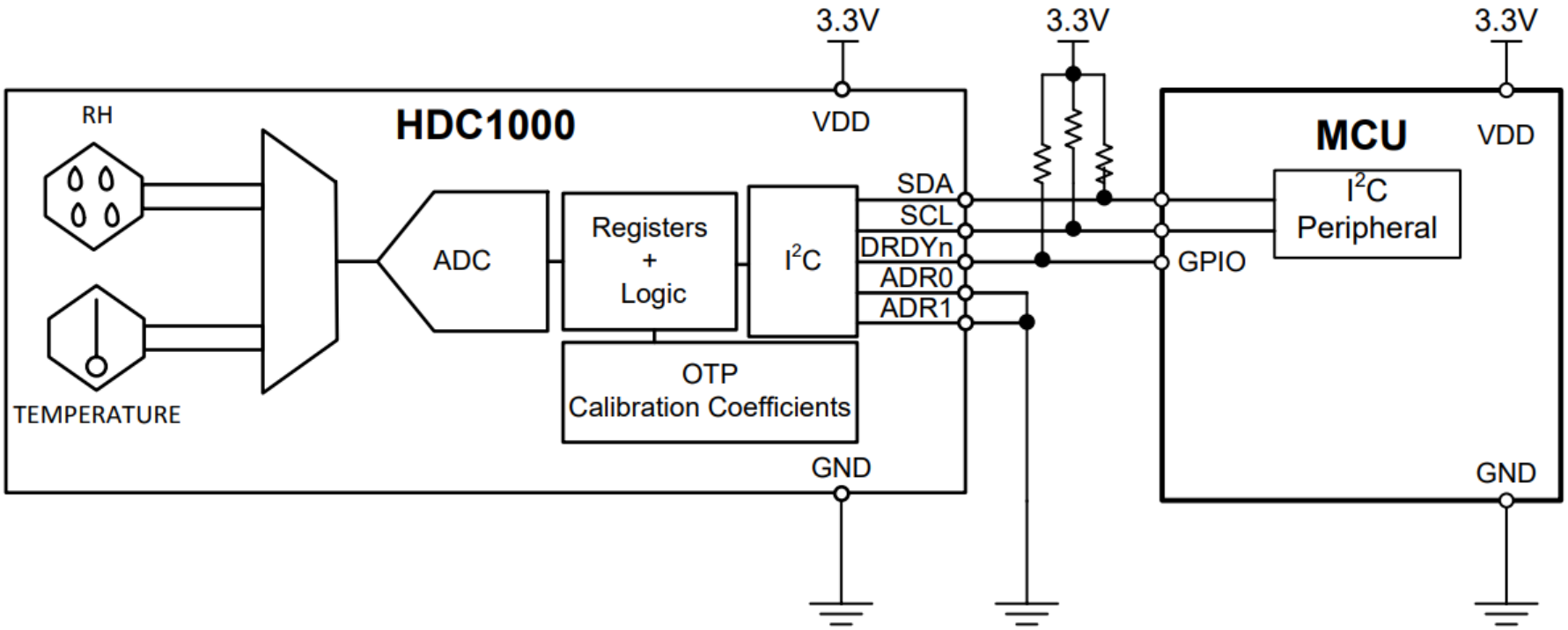


Image source: https://datasheets.maximintegrated.com

Figure 5. LIS3MDL electrical connections

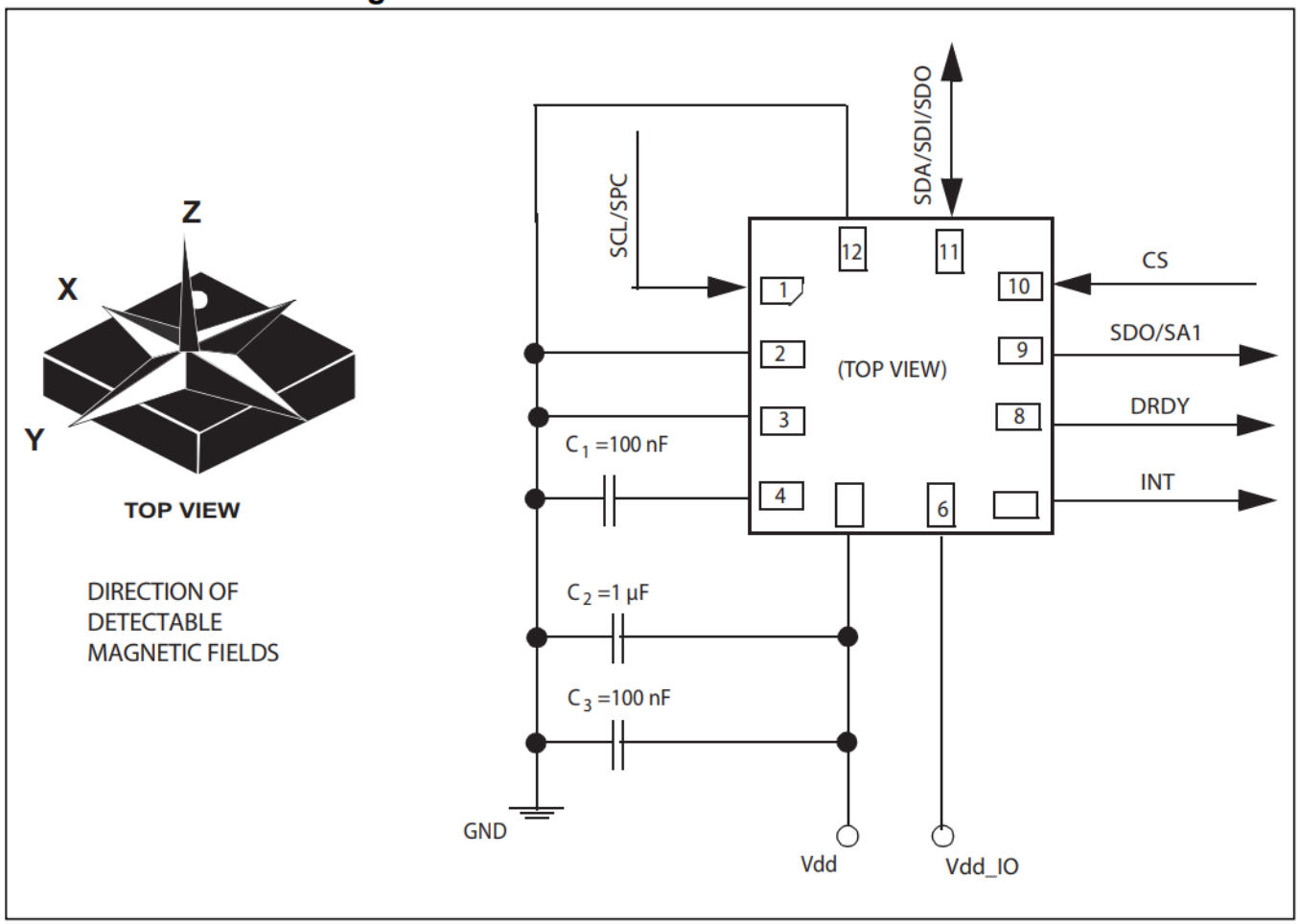


Image source: https://www.st.com/resource/en/datasheet/lis3mdl.pdf

Sensors – pressure and altitude sensor

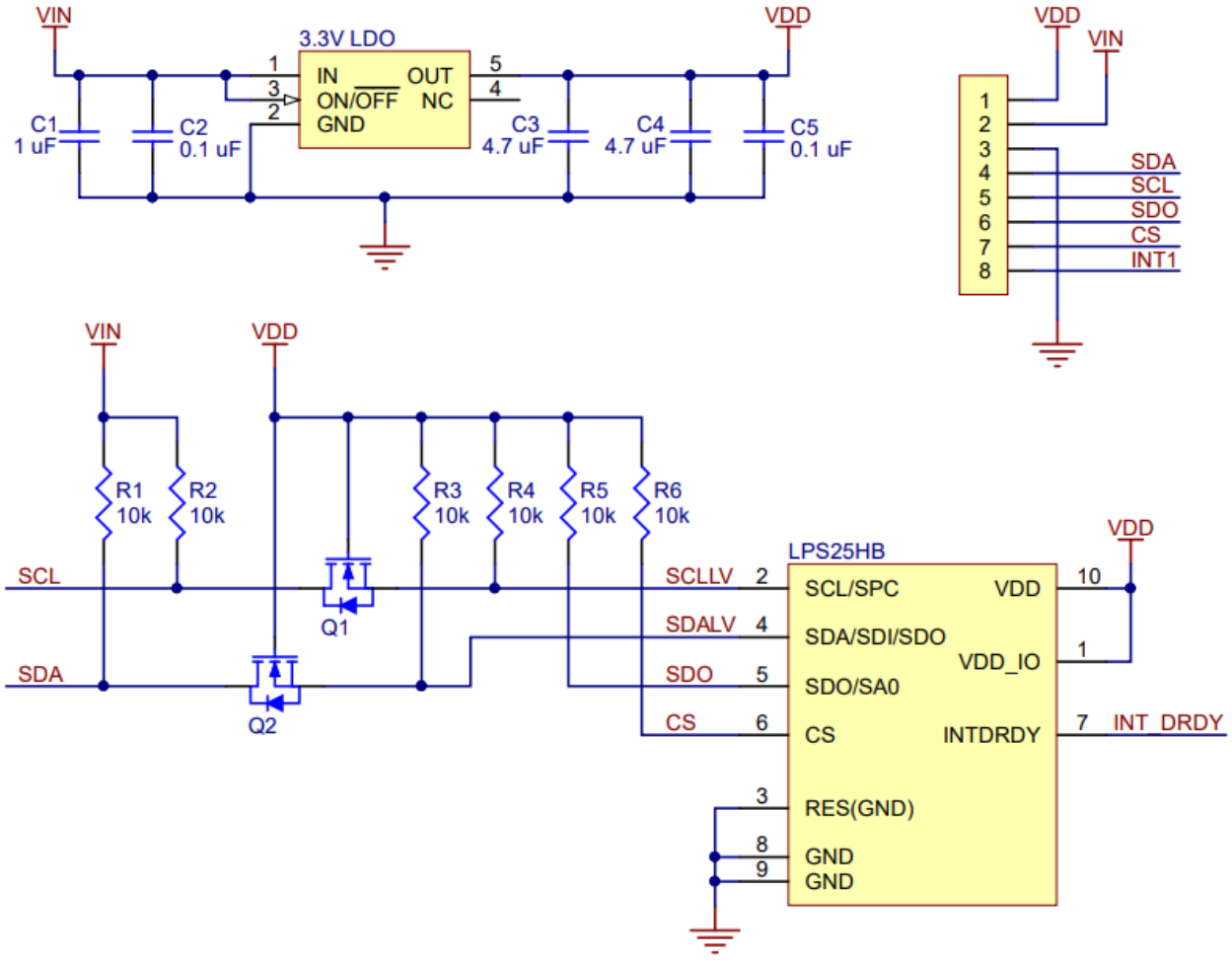


Image source: https://www.pololu.com/file/0J1575/lps25hb-pressure-altitude-sensor-carrier-with-voltage-regulator-schematic.pdf

The end – last remark

- The topic of external peripherals for microprocessor systems is very broad and it is not possible to cover everything in detail during this course.
- There are lots of other useful circuits and parts that may be used in your designs.
- If you need more information, do not hesitate to ask, but do not forget to search on your own.
- Last, but not least:

Read the datasheets...

But also check Interet forums, because even dataheets contain errors...