

Microcontroller Fundamentals

UNIVERSITY OF APPLIED SCIENCES – FH CAMPUS VIENNA



Terms and Fundamentals

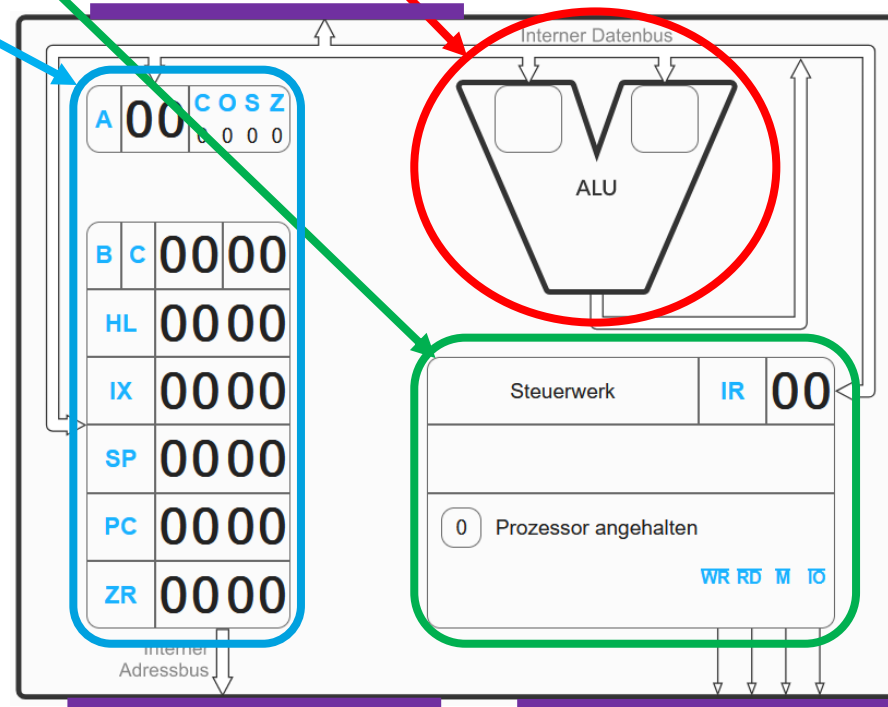
- > Microprocessor - System
- > Microcontroller
- > Eval. Board – Dev. Kit
- > Single Board Computer
- > Embedded Systems
- > Die -> Chip
- > System-on-Chip

Terms - Definitions - Microprocessor

A microprocessor consists of:

- a) an **arithmetic and logic unit** (ALU)
- b) a **control unit** (command control, instruction set)
- c) **Register** (processor-internal memory locations)

d) Connections for a **bus system**:
address,
data and
control bus



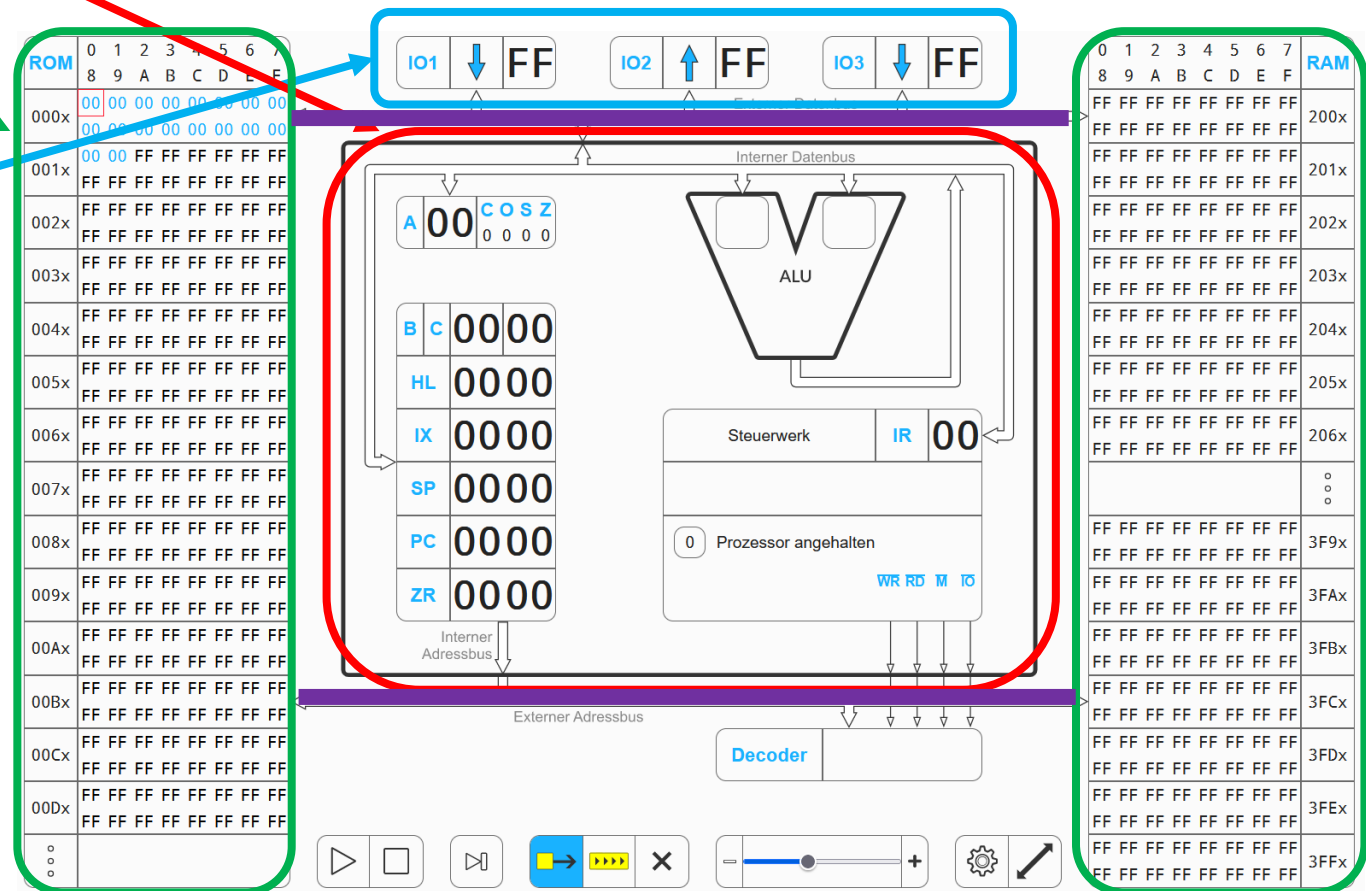
Terms - Definitions – Microprocessor - System

A microprocessor system, the simplest implementation of a working computer, consists of:

- a) **Microprocessor** (CPU)
- b) **Memory** (for instructions and data)

c) **IO-components** to interact with the environment

d) **Bussystem** to communicate between the components



Terms - Definitions – Microcontroller

A microcontroller consists of a complete microprocessor-system and additional „peripheral“-components. Inside you will find;
microprocessor, **memory**, **IO-components**, **bus-system**

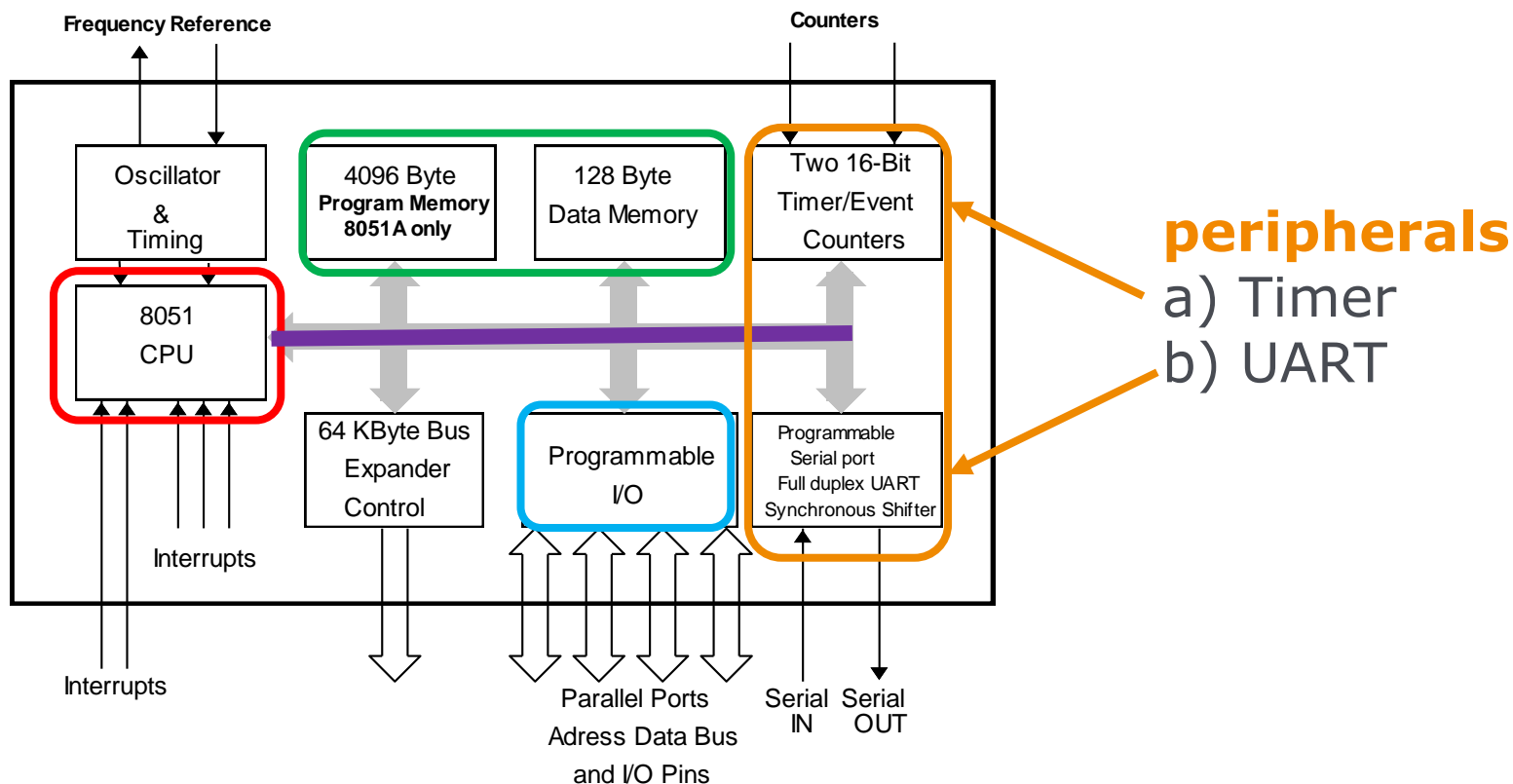


Abbildung 8051 Blockdiagramm entnommen aus: J.Walter; Aufbau von MC der 8051 – Familie
<http://books.google.at/books?id=tOpPLEjxYKsC&lpg=PA45&ots=mktES9zFKH&dq=8051%20Blockdiagramm&pg=PP1#v=onepage&q=8051%20Blockdiagramm&f=false>

Single Chip DSP

Der erste Single-Chip-DSP war der in den Bell-Labs entwickelte DSP1 (Bild), den AT&T/Western Electric 1979 auf den Markt gebracht hat. Er bildete die Schlüsselkomponente des digitalen Schalters ESS. Zu den kommerziell erfolgreichsten frühen DSPs gehörte der Festkomma-DSP μ PD7720 von NEC, der 1980 für Sprachanwendungen eingeführt wurde. Der damals schnellste DSP war jedoch der TMS32010, den Texas Instruments am 8. April 1983 präsentierte. Der programmierbare 16-Bit-DSP konnte eine Multiplikations-Operation in 200 ns berechnen und Befehle sowohl aus dem On-Chip-ROM als auch aus dem Off-Chip-RAM ausführen. Bei einem Preis von 500 US-Dollar pro Stück wurden im ersten Jahr (1983) etwa 1.000 Stück verkauft. Der Mikroprozessor war danach in vielen Varianten mit Fest- und Fließkomma-Arithmetik (Reihe TMS320) erhältlich. Die Chips wurden in Consumer-Produkten vom Handy bis zum Spielzeug und in der Computergrafik (Apollo-Workstation DN570) verwendet. // KR

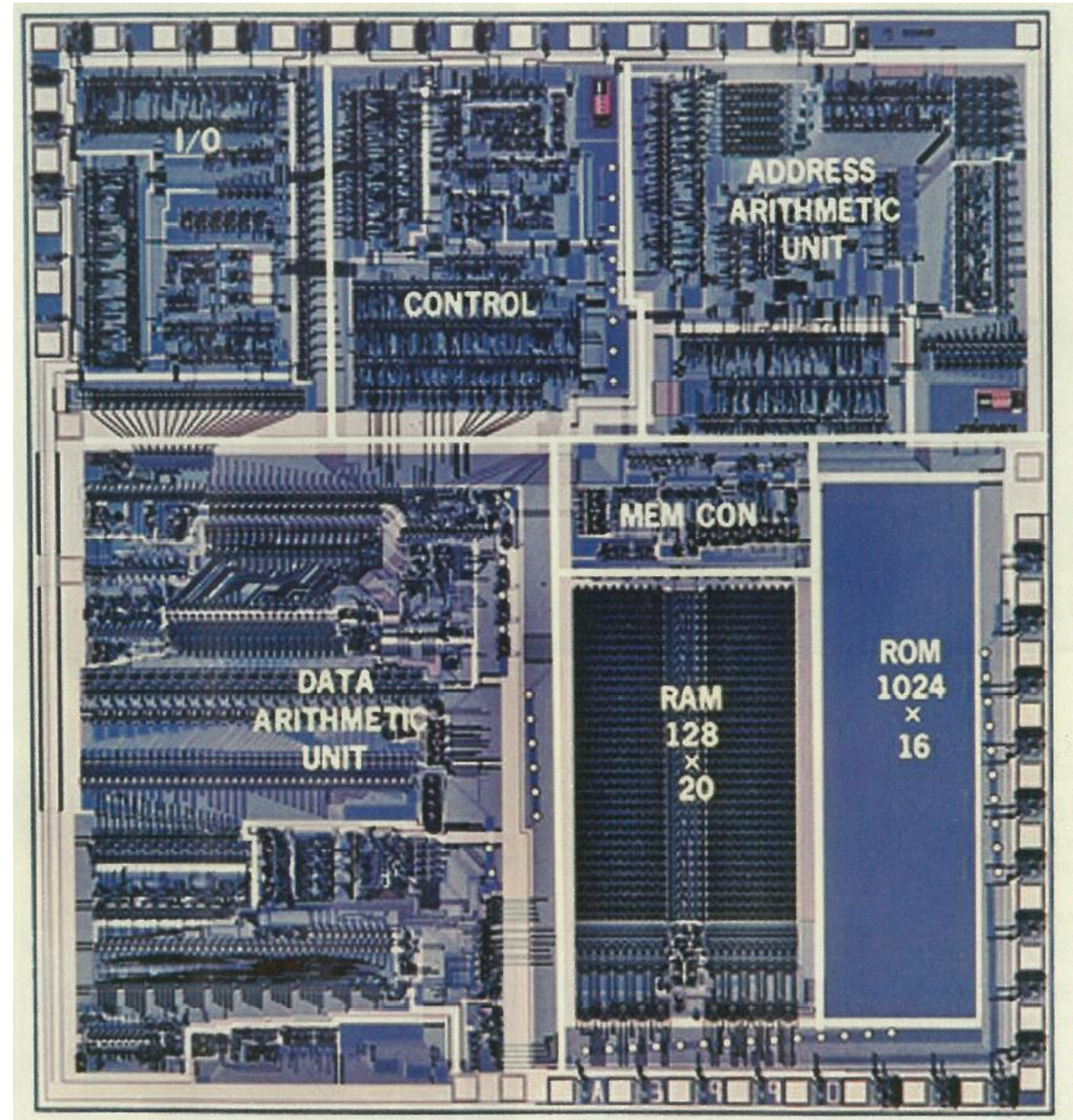
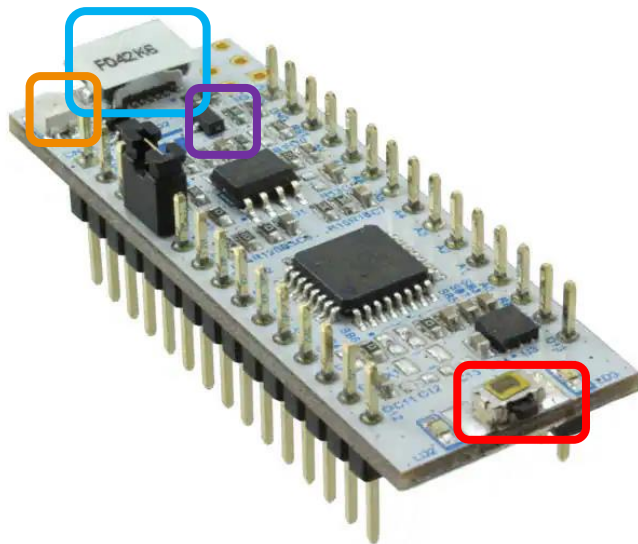


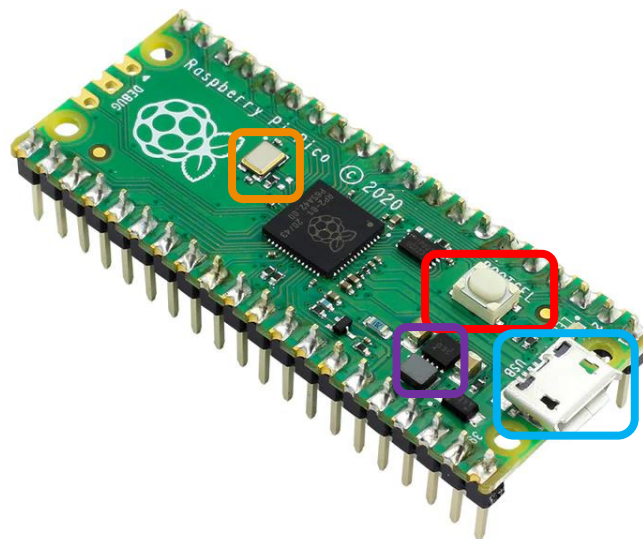
Abbildung entnommen aus Elektronikpraxis 3 - 2022

Microcontroller – Eval.board – Dev.Kit

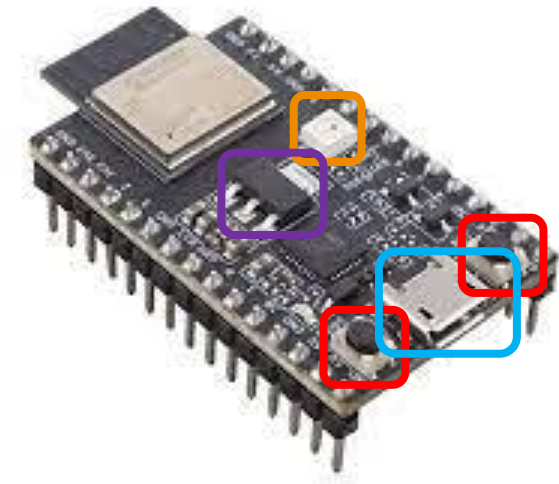
For simple experiments, a microcontroller is mounted on a small circuit board together with a **button**, an **LED**, a **USB socket** (connection to the development PC and power supply) and a **voltage converter** (usually 5V to 3.3V). These boards are called evaluation boards or development kits. The pins are connected using so-called jumpwires (cables), several pins in line form a pin header.



STM32 Nucleo Nano



Raspberry Pi Pico



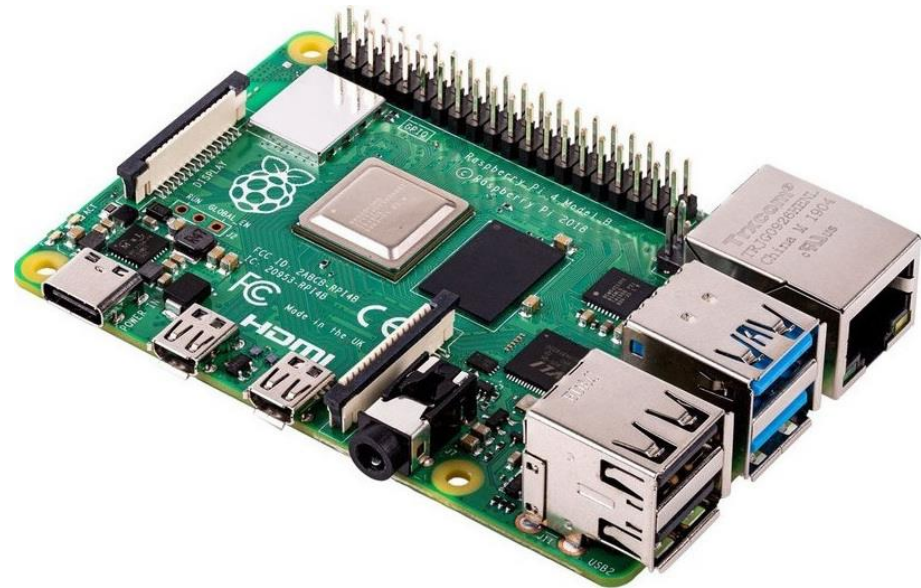
ESP32

Microprocessor – Single Board Computer (SBC)

A microprocessor is often combined with memory and standard connections (Ethernet, USB, HDMI ..) on a "small" circuit board to become a so-called "single-board computer". Well-known representatives of this type are the Raspberry Pi, the Beagleboard



Beagleboard X15



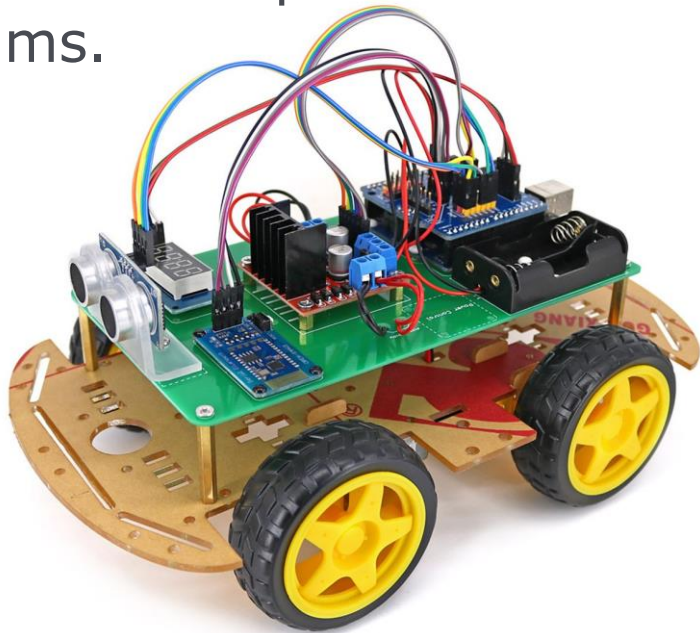
Raspberry Pi 4

<https://www.electronics-lab.com/top-10-single-board-computers-of-2020/>

Embedded Systems – Eingebettete Systeme

If microcontrollers (μC) (or entire single board computers SBC) are used for a very special task and built into a larger system for this purpose, we speak of embedded systems.

For example, a microcontroller can receive data via a radio module and thereby control a vehicle. But you need to use a Raspberry Pi with a connected camera to control an autonomously driving vehicle, because more calculation power is needed for the complex image processing algorithms.



<https://www.dx.com/p/4wd-bluetooth-controlled-smart-robot-car-kit-w-installation-tutorial-demo-code-for-arduino-2057165.html>



<https://www.xiaorgeek.net/products/xiaor-geek-ds-wireless-wifi-robot-car-kit-for-raspberry-pi-4b>

Embedded Systems – Embedded **Electronic & Computer** Systems

To define the term a little more precisely, a **computer system** (μC , SBC, SoC, ..) which is to be **programmed** for the **specific application** (exactly only one, e.g.: washing machine, flying drone, combustion engine), **together with** the **necessary electronic components** required for this application (Amplifiers, switches, sensors, ...) integrated into a larger system that **completely fulfills** an application.

A combination of electronic components is always required to influence physical variables in order to completely fulfill the application. The type of influence is determined by the electronic circuit in combination with the integrated software.

„A dedicated computer performing a specific function as a part of a larger system“ – „usually not visible from the outside“

Embedded Electronic & Computer Systems

Integrating a lot of "peripherals" in a microcontroller enables the solution of many different tasks. The goal is the best combination of "application software" interacting with the integrated electronic circuits configured for a specific application (timer, ADC, ...). These tasks used to be performed solely by complex applications specific integrated circuits. (ASICs)

„Turn hardware problems into software problems“

F35 - 2006

30 million lines of code



<https://www.military.com/equipment/f-35a-lightning-ii>

F150 - 2017

150 million lines of code



<https://autogazette.de/fahrberichte/ford/f-150/ford-f-150-raptor-exotisches-raubtier-624502.html>

Embedded Systems – Modern Definition

High-reliability systems operating in a resource-constrained environment (typically: costs, space & power)

Excludes general-purpose computers, and non computerized devices!

Often applied to mobile computing due to similarity in requirements (lightweight = space, power = battery), although not „embedded“ per se

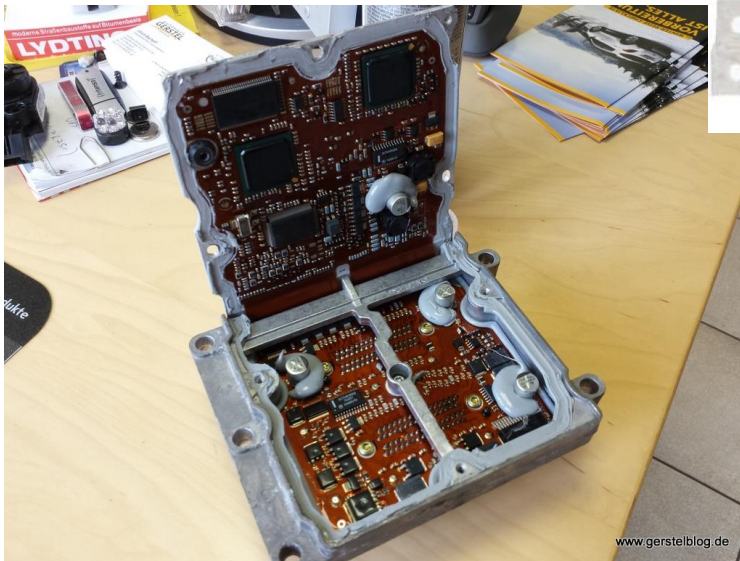
No external visible difference between hardware and software functions

Well-defined, fundamental, and extremely performance-sensitive functions are generally implemented in hardware. **Still today!!!!**

Complex, non-performance-sensitive, and/or likely-to-change functions are generally implemented in software.

Embedded Systems

Engine control unit – ECU Opel



<https://www.gerstelblog.de/2014/02/14/ein-motorsteuergeraet-in-nahaufnahme/>

Wasching maschine- control board

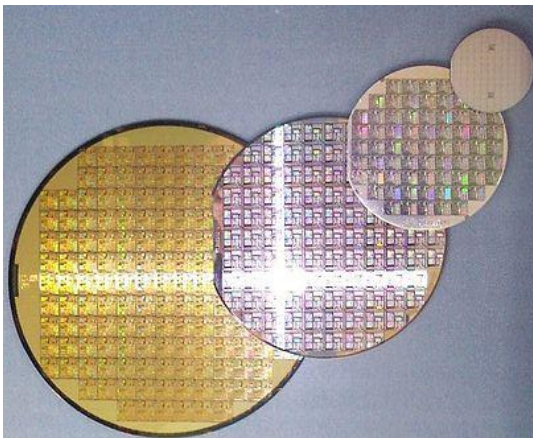


<https://www.amazon.de/Elektronik-Waschmaschine-Waschautomat-Beko-2826740303/dp/B07RCJCQ2G>

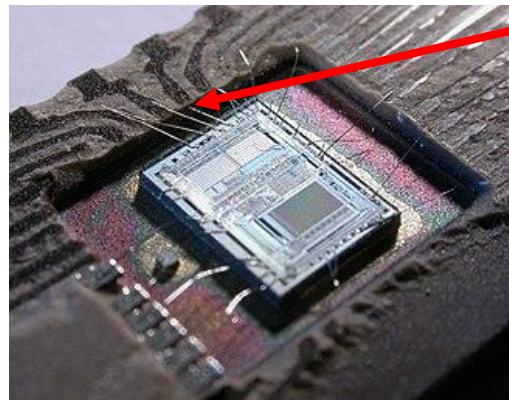
Die (englisch für „Würfel“, „Plättchen“, dt. Plural i. A. „Dies“)

An “integrated circuit” (IC) also known as a chip is manufactured using both chemical and physical processes in semiconductor technology. The substrate used here is usually a disc of a semiconductor monocrystal (usually silicon) less than a millimeter thick, a so-called **wafer**. The electronic components and circuits are realized in an area close to the surface (max. 1 µm deep) on one side of the wafer. The area for a single processor (or integrated circuit) is called a "**die**".

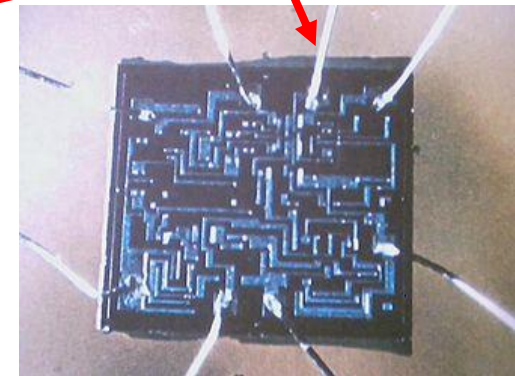
In the mostly black plastic housing of an IC there is a "**die**" (this is the actual circuit which is built on a thin plate (chip) made of silicon) which is connected to the metal connection pins of the plastic housing with **bonding wires**.



Halbleiter Wafer



Die Intel 8742



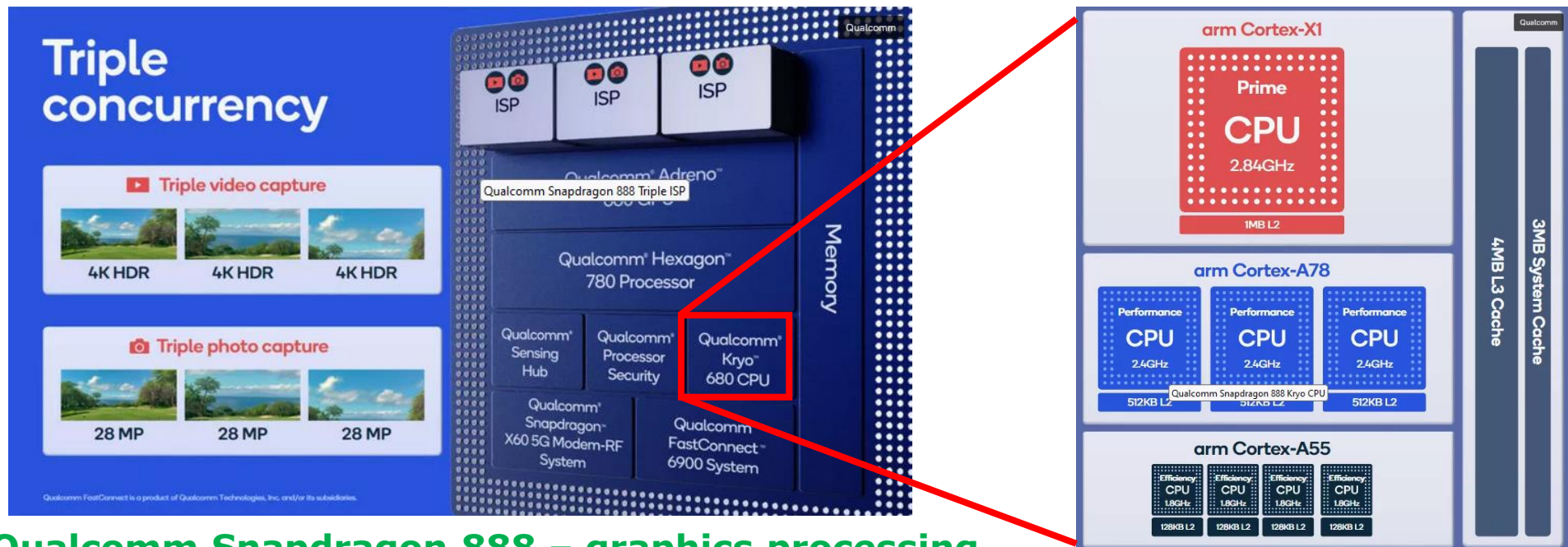
Bonding wires

[https://de.wikipedia.org/wiki/Die_\(Halbleitertechnik\)](https://de.wikipedia.org/wiki/Die_(Halbleitertechnik))

SoC – System on Chip – example Snapdragon 888

We call it a system-on-chip if more than one processor/computing core is integrated in an "integrated circuit" (IC for short), also known as a chip. (e.g.: Kryo 680)

This is often a microprocessor together with other components such as radio modems (LoRa, BLE, Wifi) and a dedicated graphics processing unit (**GPU**) for controlling the screen or processing data from image sensors (cameras).



Qualcomm Snapdragon 888 – graphics processing

Kryo 680 CPU

<https://www.androidauthority.com/qualcomm-snapdragon-888-1179156/>

SoC – System on Chip – Example STM32WL55

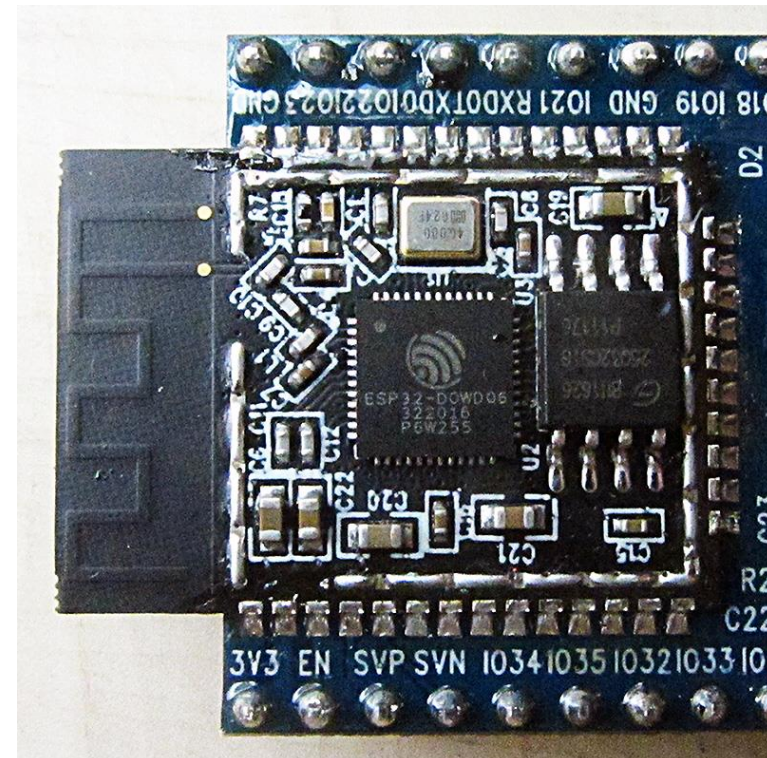
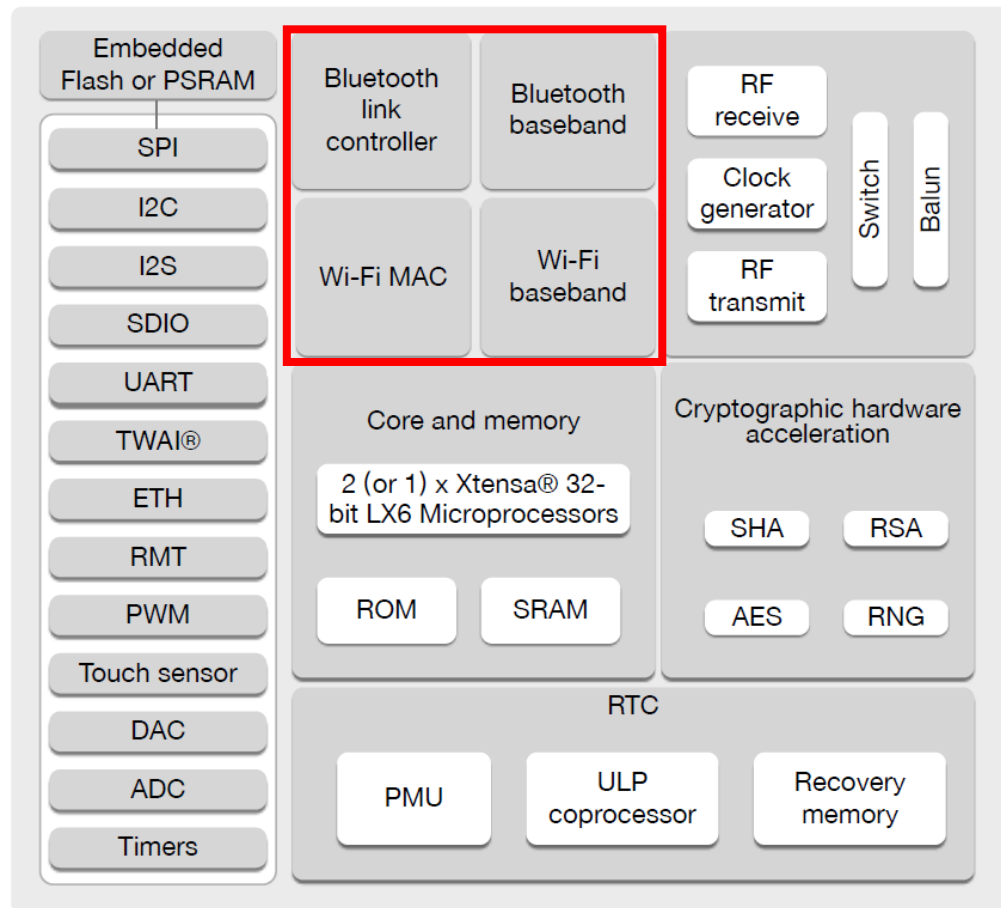
The latest models of the STM32 family represent a further development from "classic" microcontrollers through the integration of various radio modems (LoRa, BLE, Wifi) to the SoC.



<https://www.st.com/en/microcontrollers-microprocessors/stm32wl-series.html>

SoC – System on Chip – Example ESP32

The Chinese company Espressif has been offering the ESP32 since 2016, a SoC with one or two Xtensa CPU cores and integrated WLAN and Bluetooth.



<https://www.espressif.com/en/products/socs>



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