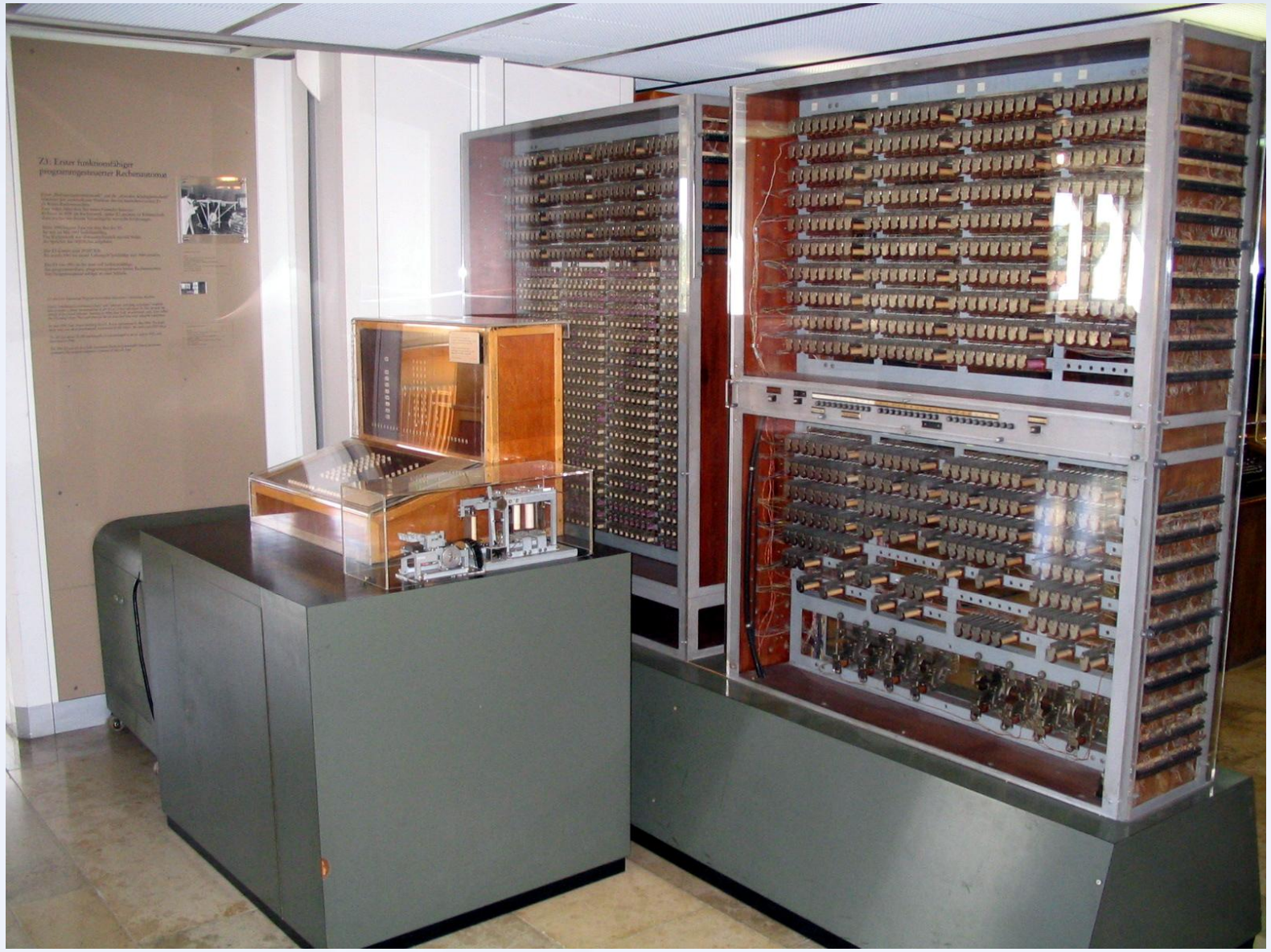
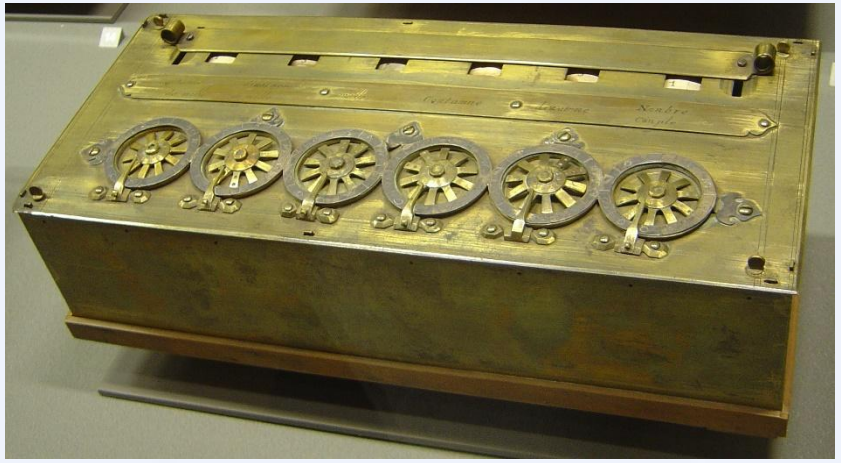
# От Ардуино к микроконтроллеру

(Введение в программирование микроконтроллеров)

Мушников Игорь



12 мая **1941** г. – демонстрация первой рабочей программируемой вычислительной Z3 машины Конрадом Цузе



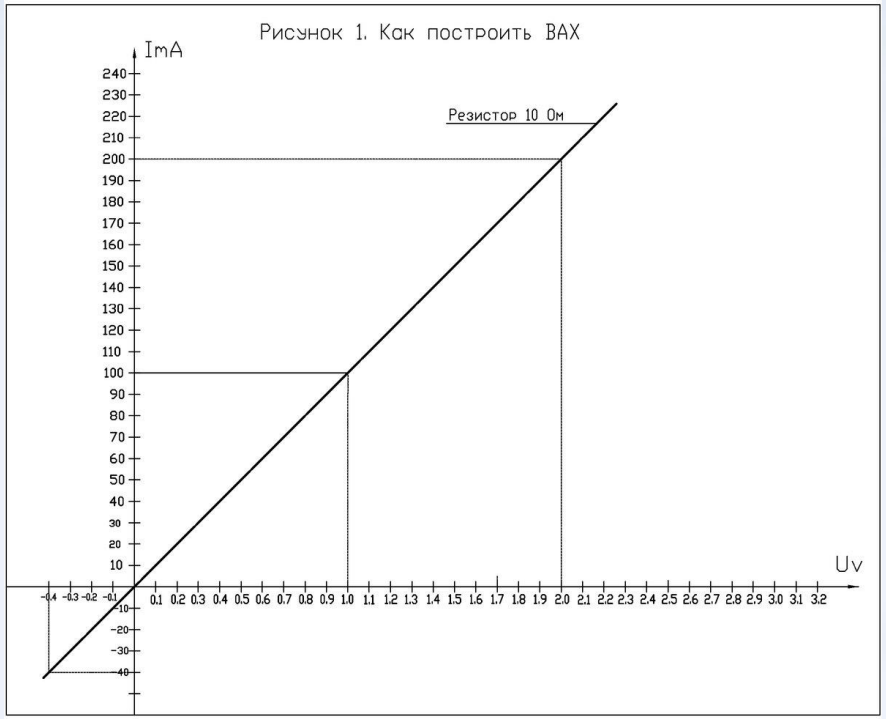
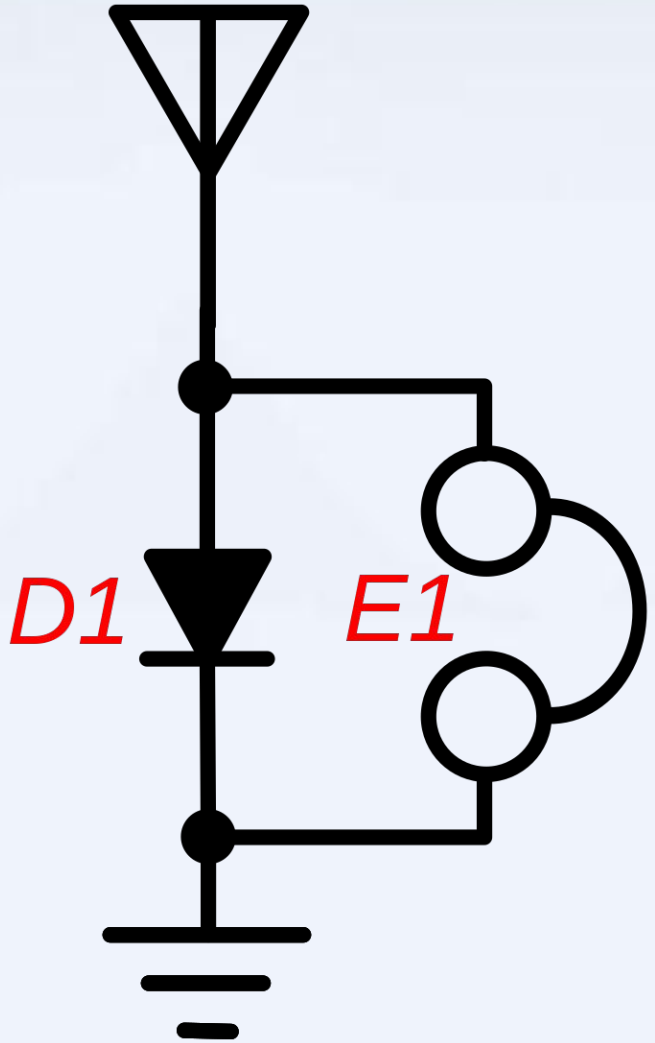
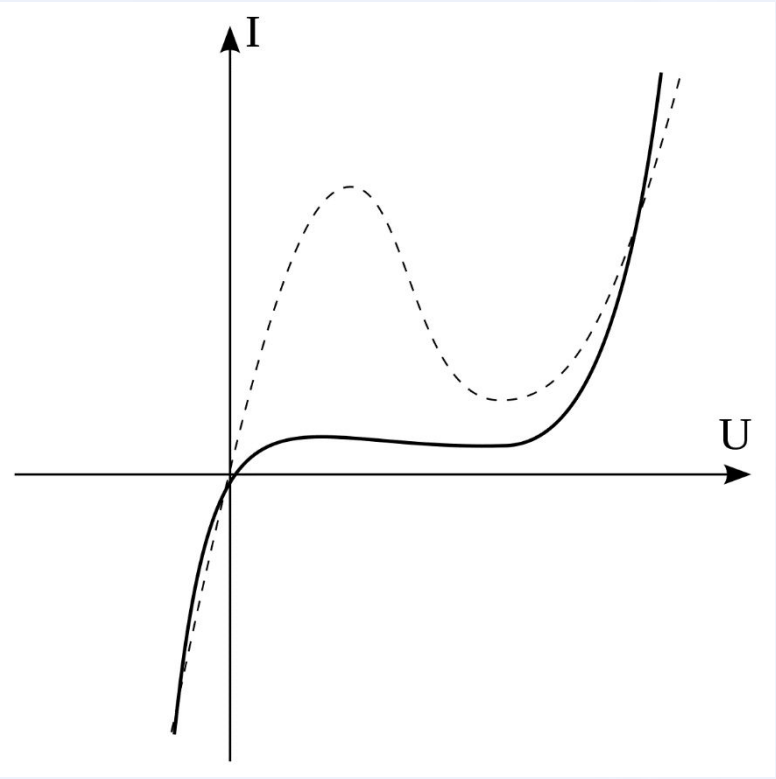
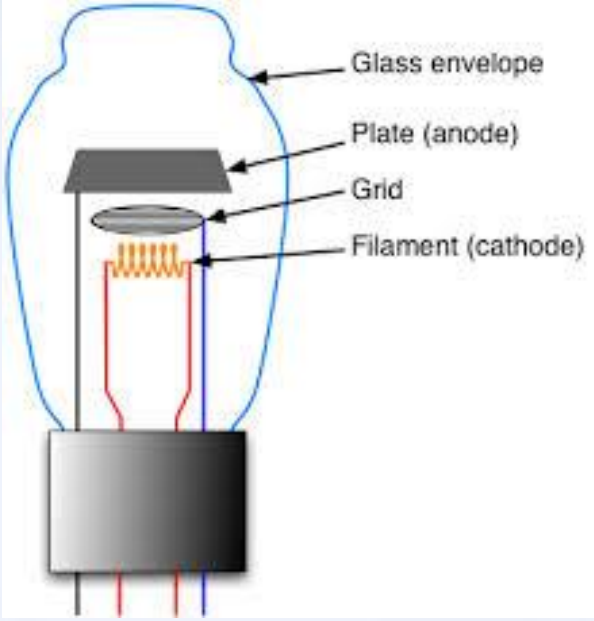


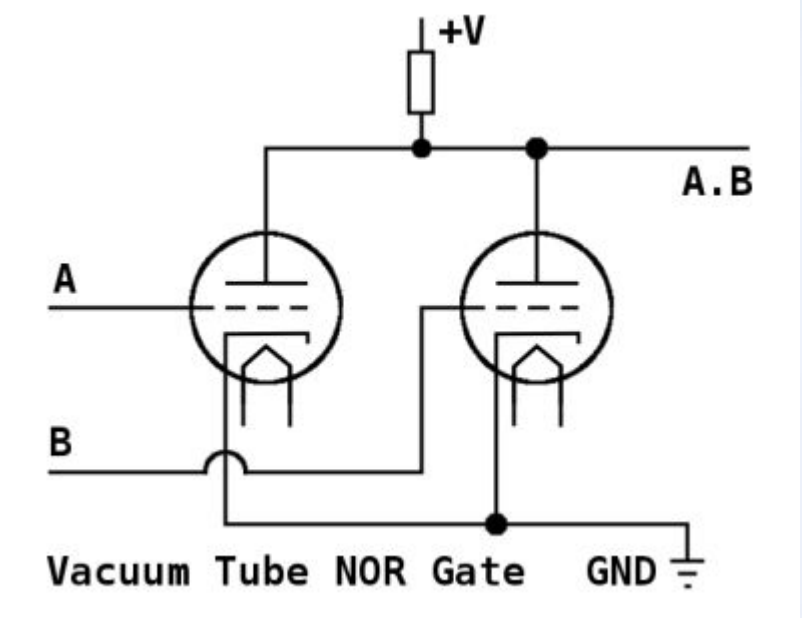
Рисунок 1. Как построить ВАХ
ImA
Резистор 10 Ом
Uv

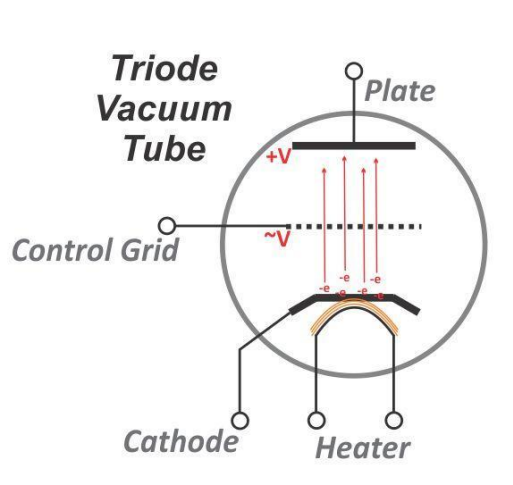

D1
E1

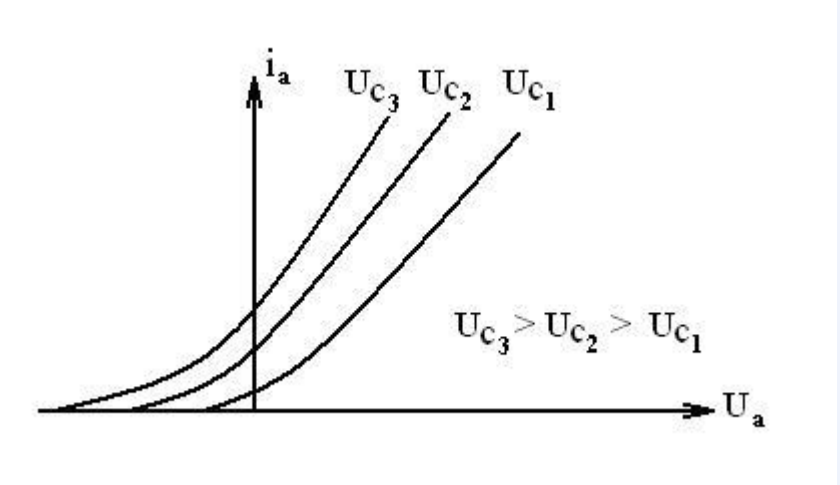

I
U

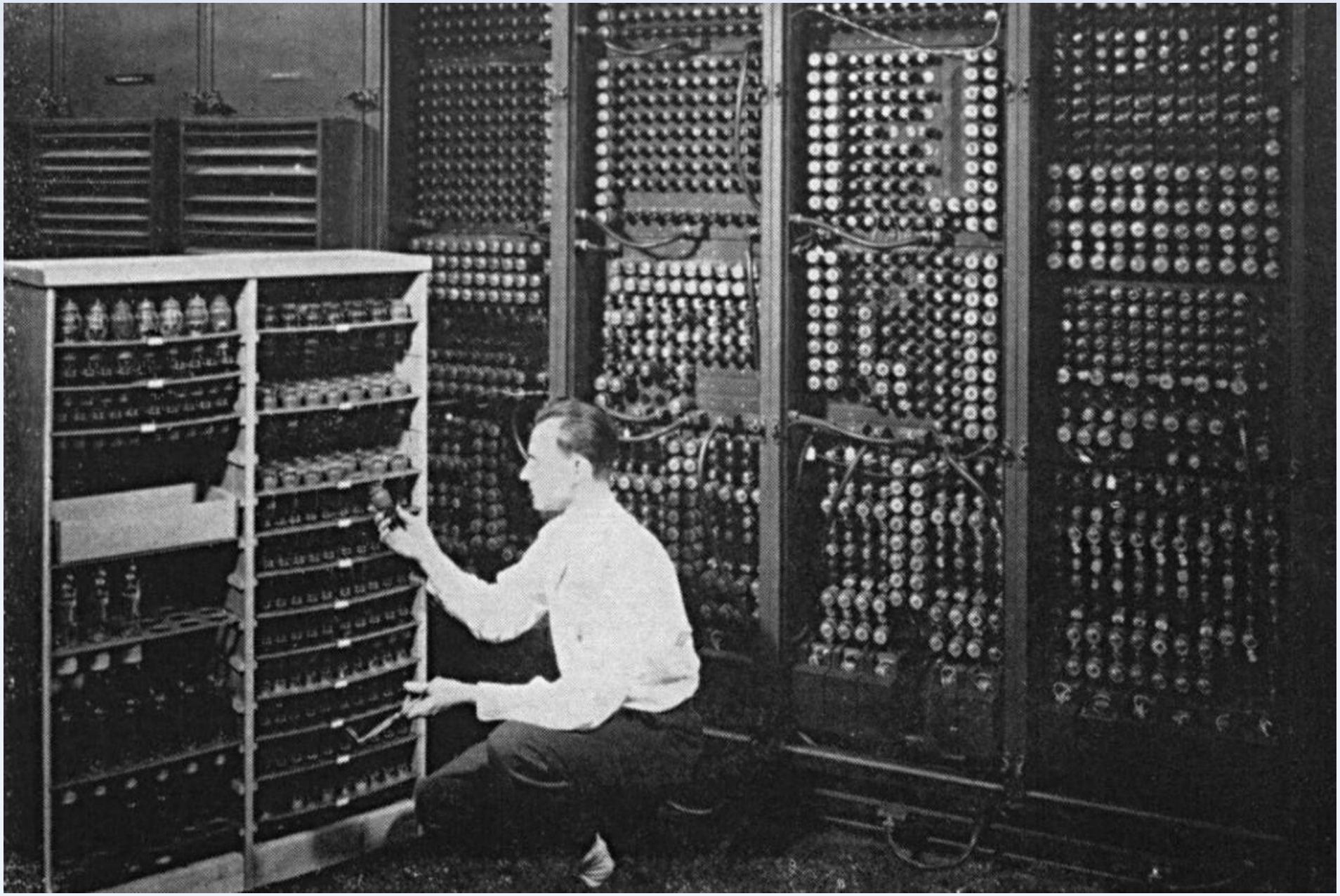
EL84E-H
Made in Russia
12 07

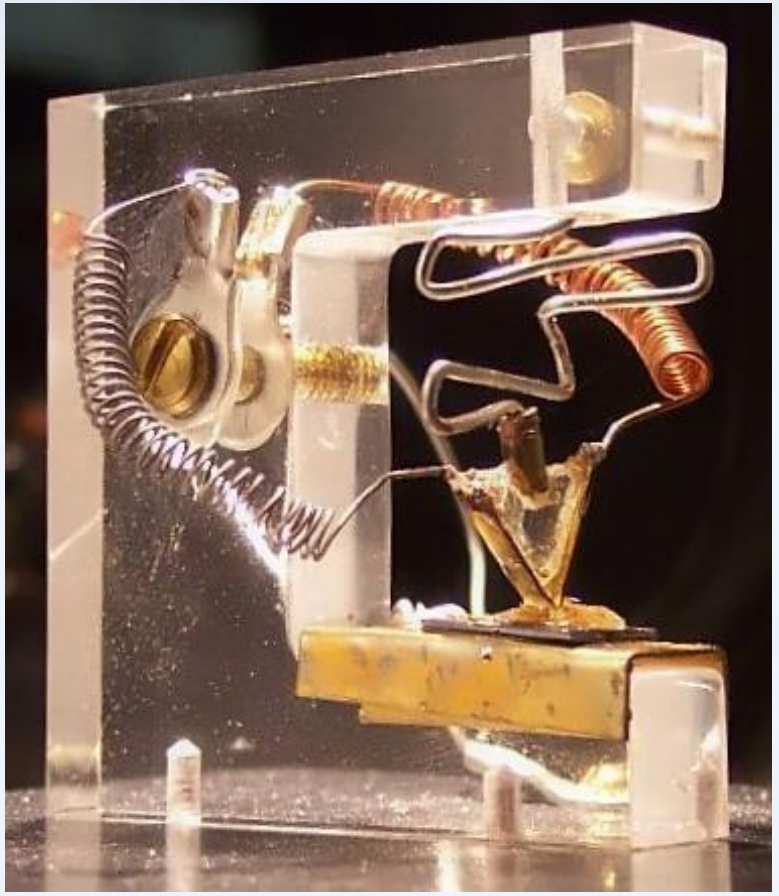

Glass envelope
Plate (anode)
Grid
Filament (cathode)


+V
A.B
A
B
Vacuum Tube NOR Gate
GND


Triode Vacuum Tube
Plate
+V
Control Grid
~V
Cathode
Heater


$i_a$
$U_{c_3}$ $U_{c_2}$ $U_{c_1}$
$U_{c_3} > U_{c_2} > U_{c_1}$
$U_a$





Бардин, Шокли и Браттейн в лаборатории Bell
1948
Лауреаты Нобелевской премии 1956

AMD

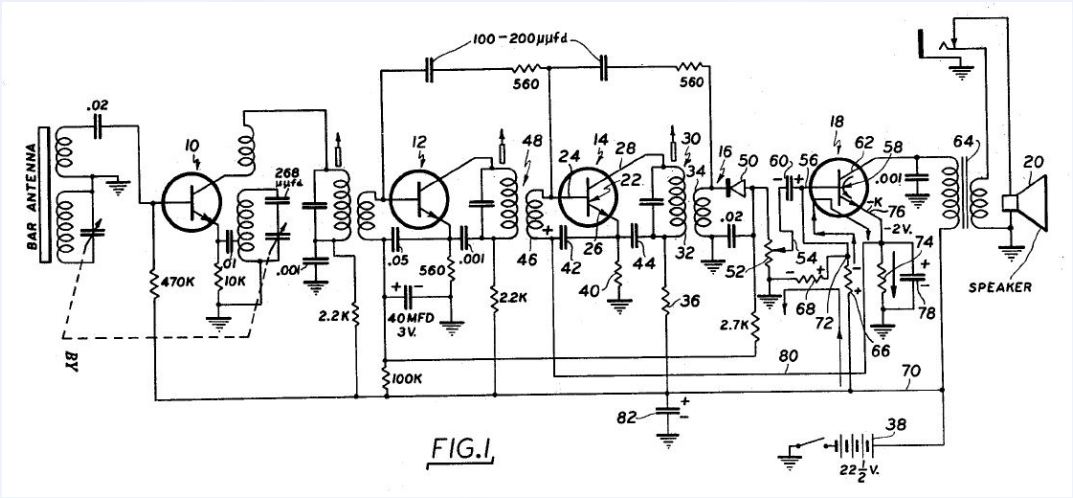
intel

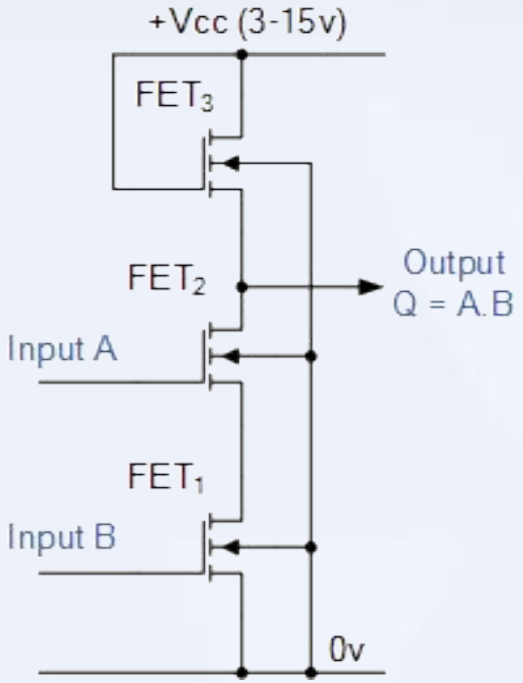
MICROCHIP

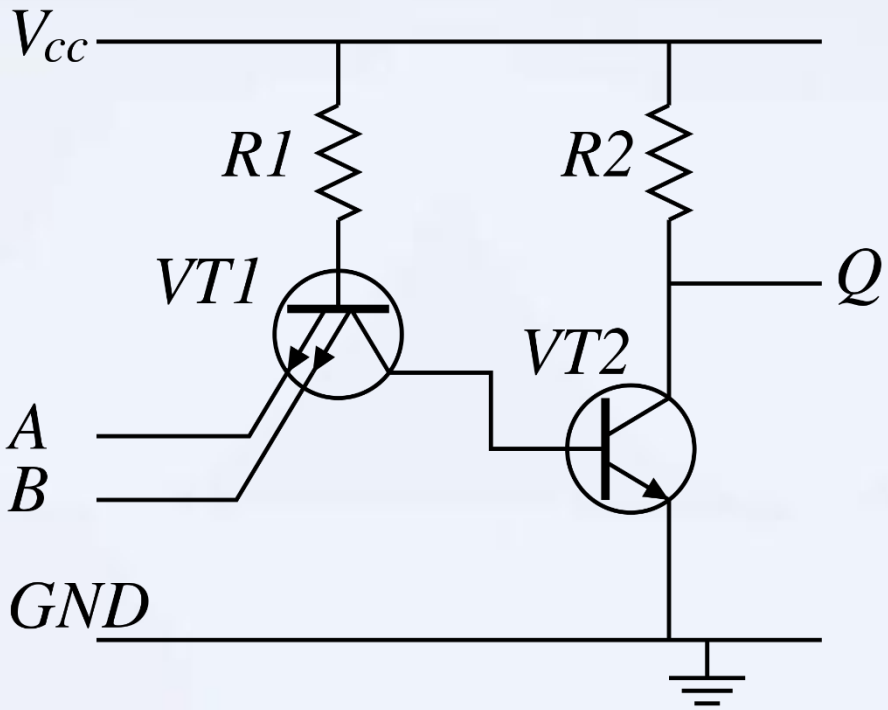
intersil

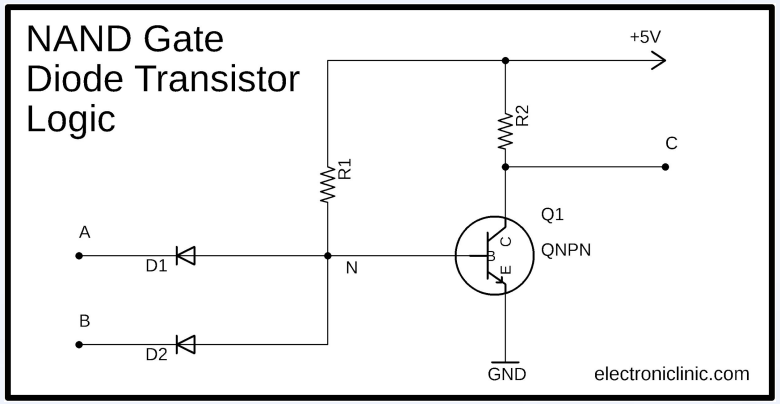
National Semiconductor

TEXAS INSTRUMENTS

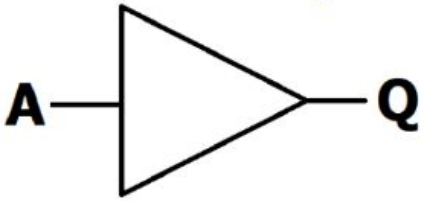



+Vcc (3-15v)
FET3
FET2
Output
Q = A.B
Input A
FET1
Input B
0v


Vcc
R1
R2
VT1
VT2
Q
A
B
GND

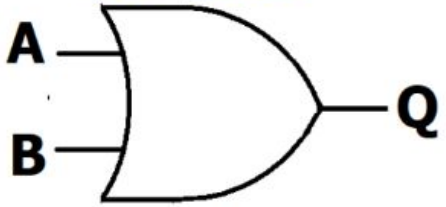

NAND Gate
Diode Transistor
Logic
+5V
R2
C
R1
Q1
QNPN
A
D1
N
B
D2
GND
electroniclinic.com

## Buffer Amp



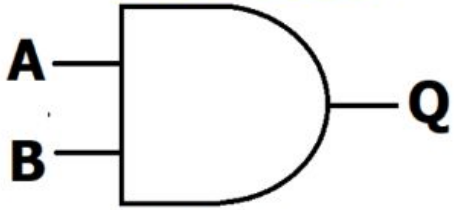

| A | Q |
|---|---|
| 0 | 0 |
| 1 | 1 |

## OR Gate



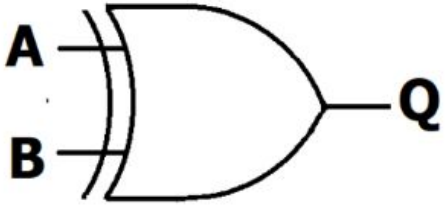

| A | B | Q |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 1 |

## AND Gate



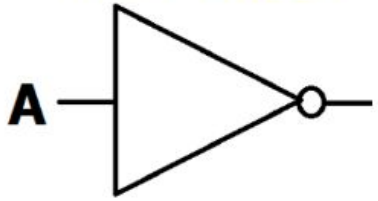

| A | B | Q |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

## EX-OR Gate



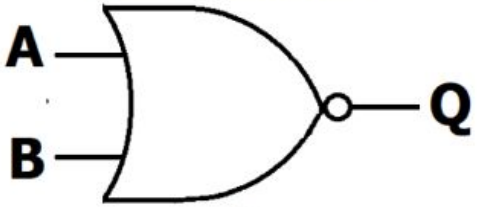

| A | B | Q |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

## NOT Gate



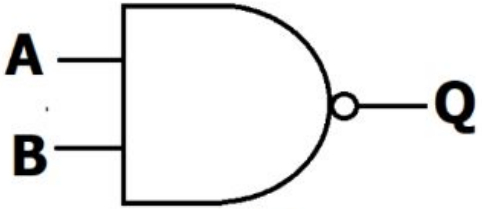

| A | Q |
|---|---|
| 0 | 1 |
| 1 | 0 |

## NOR Gate



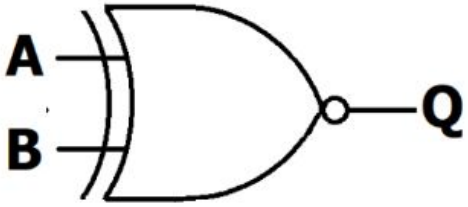

| A | B | Q |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 0 |

## NAND Gate

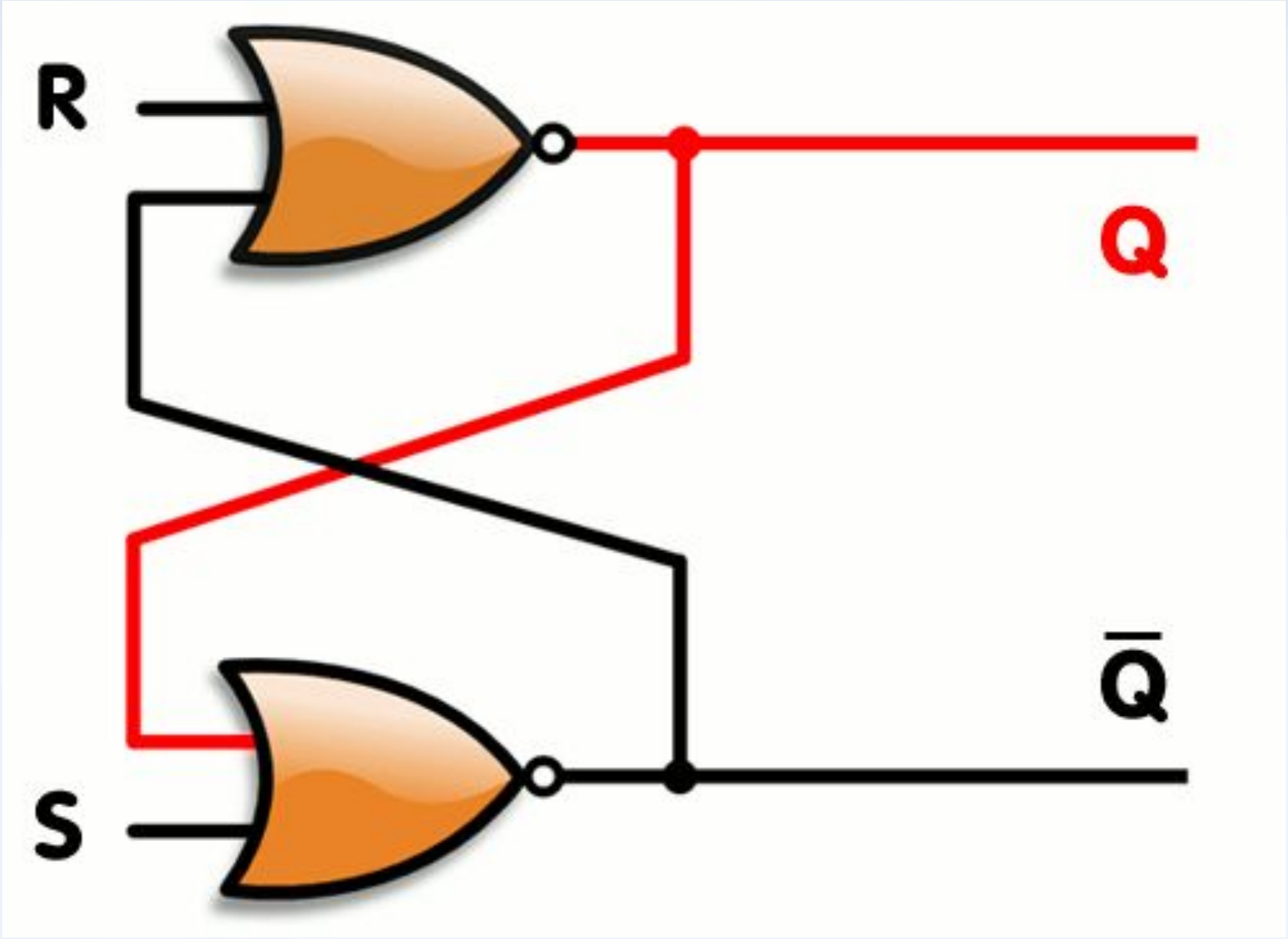


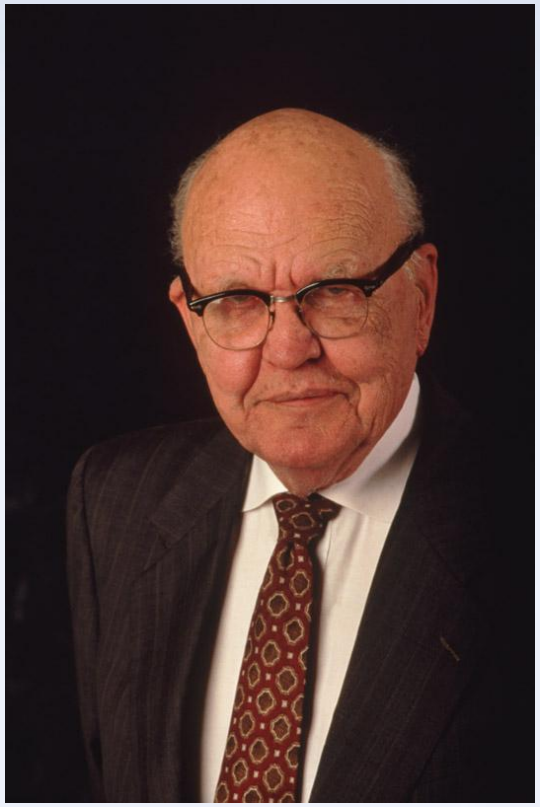

| A | B | Q |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

## EX-NOR Gate



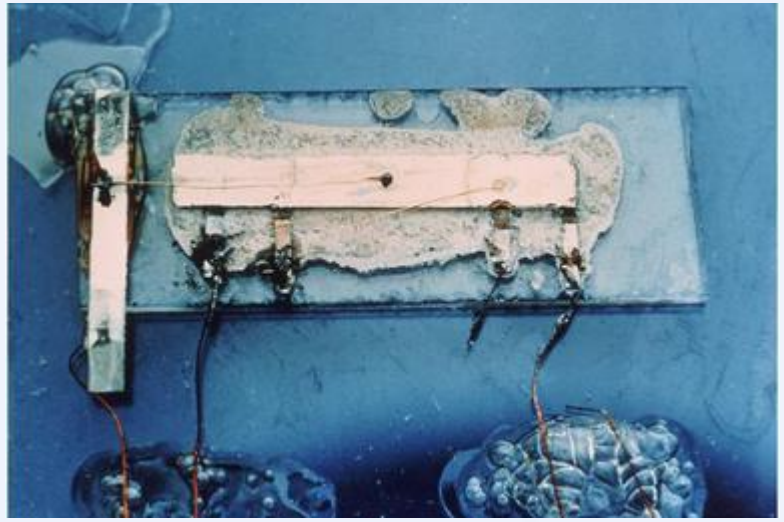

| A | B | Q |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

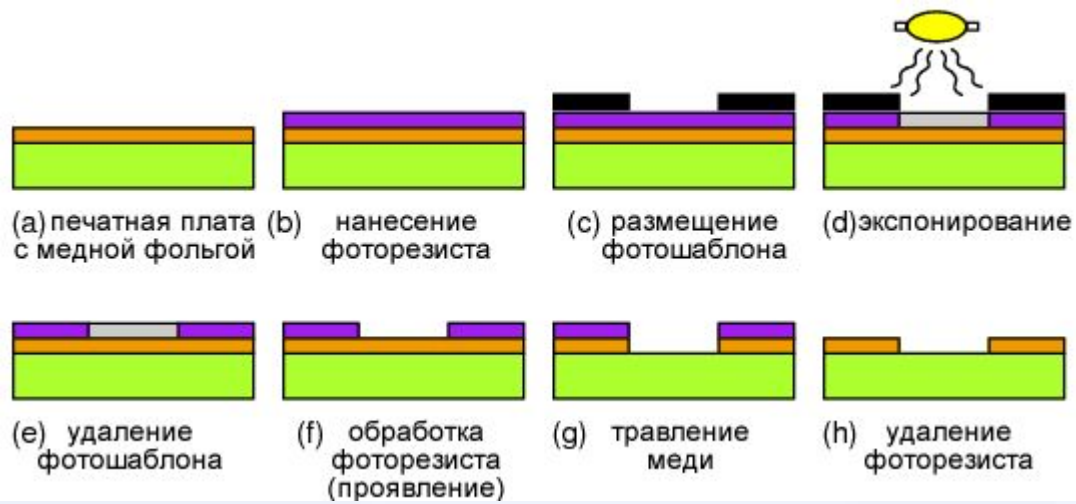

R
S
Q
$\bar{Q}$

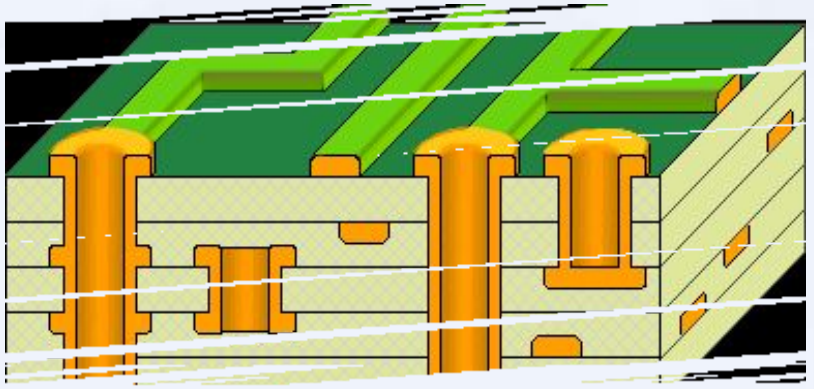


Джек Килби и Роберт Нойс
– первые изобретатели ИС (**1958**)

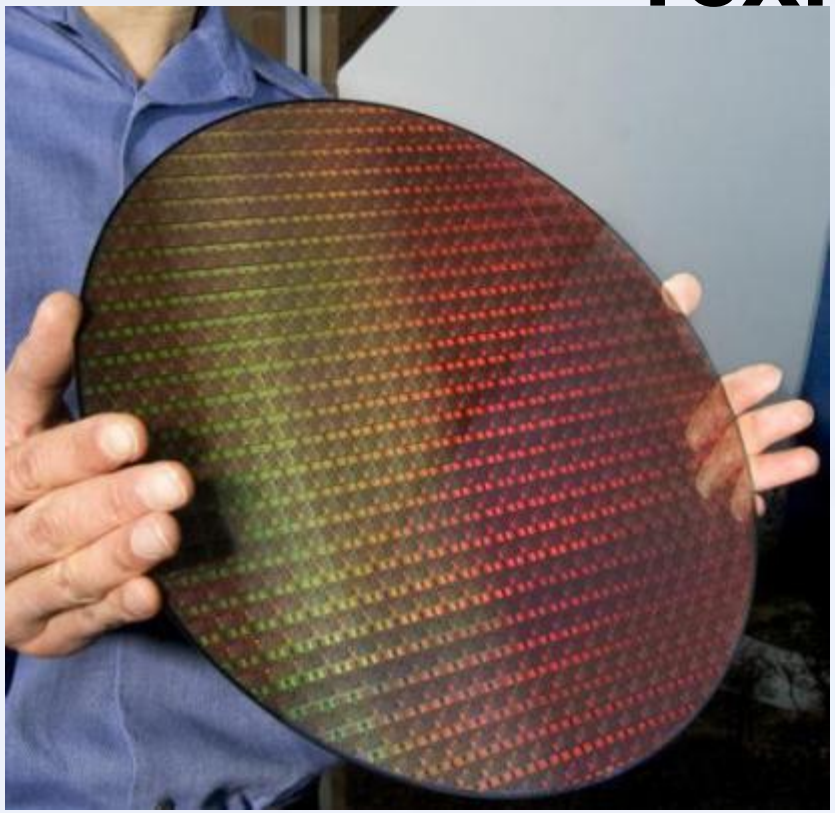
Нобелевская премия по физике 2000

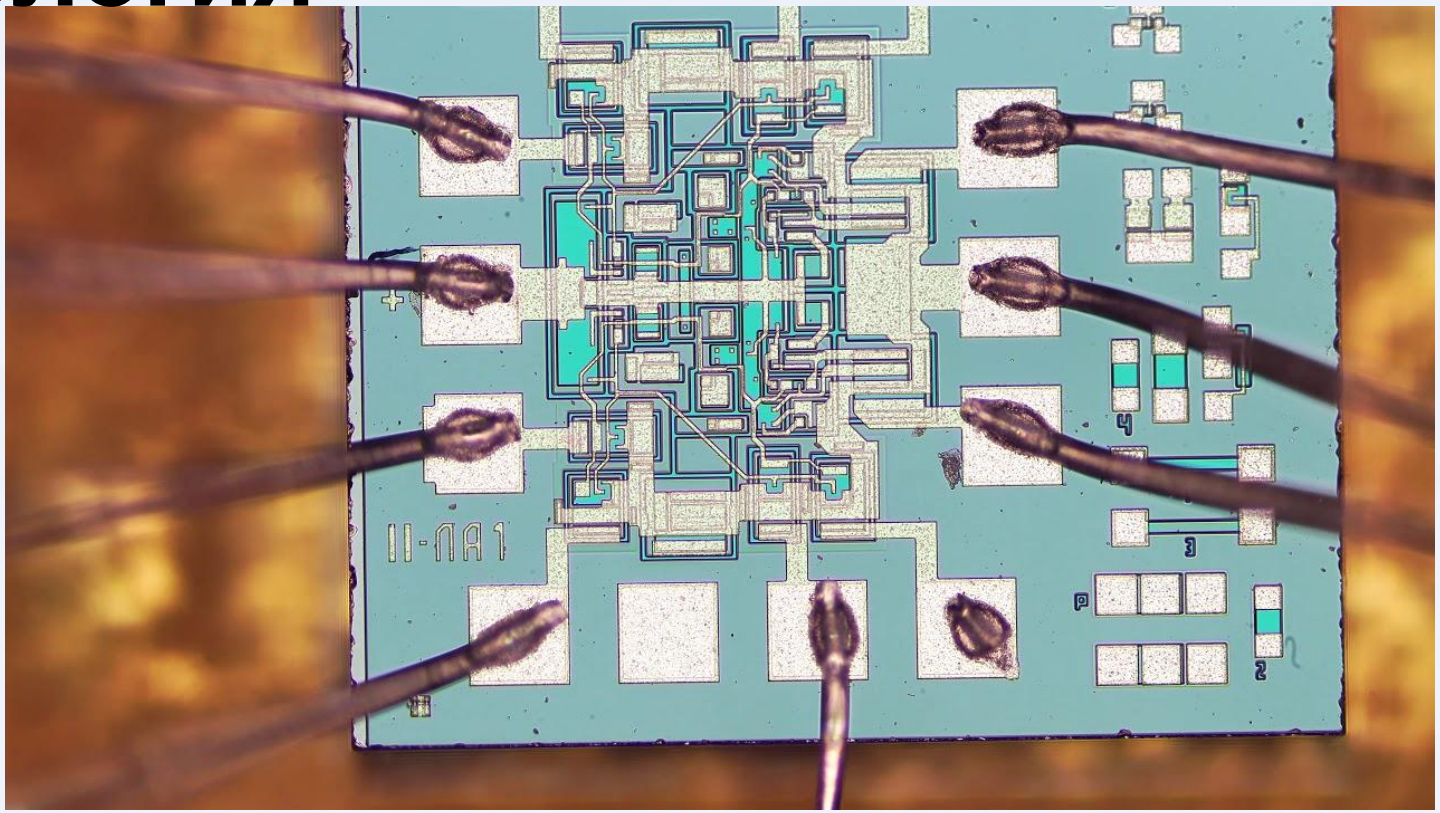



(a) печатная плата с медной фольгой
(b) нанесение фоторезиста
(c) размещение фотошаблона
(d) экспонирование
(e) удаление фотошаблона
(f) обработка фоторезиста (проявление)
(g) травление меди
(h) удаление фоторезиста

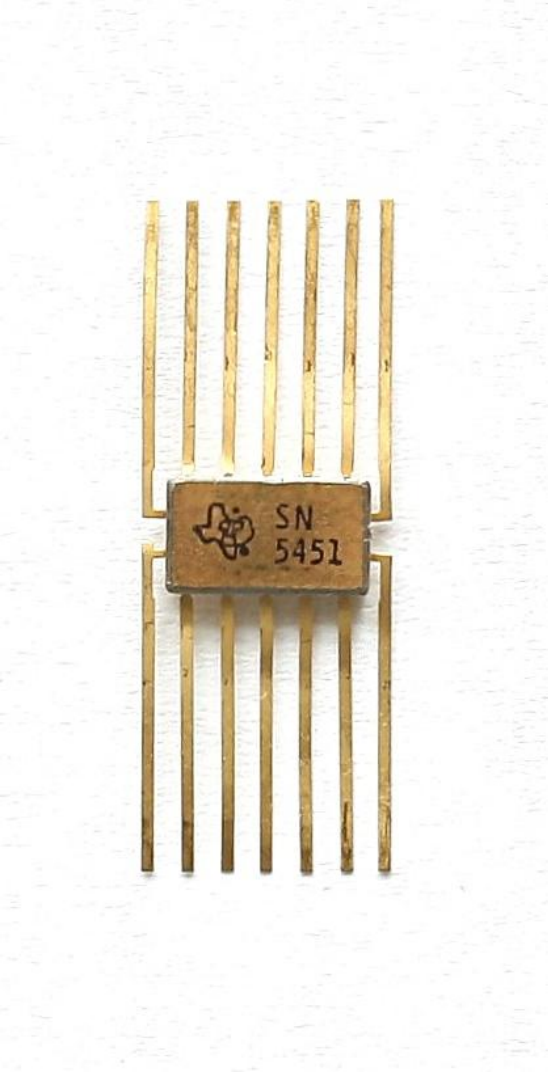


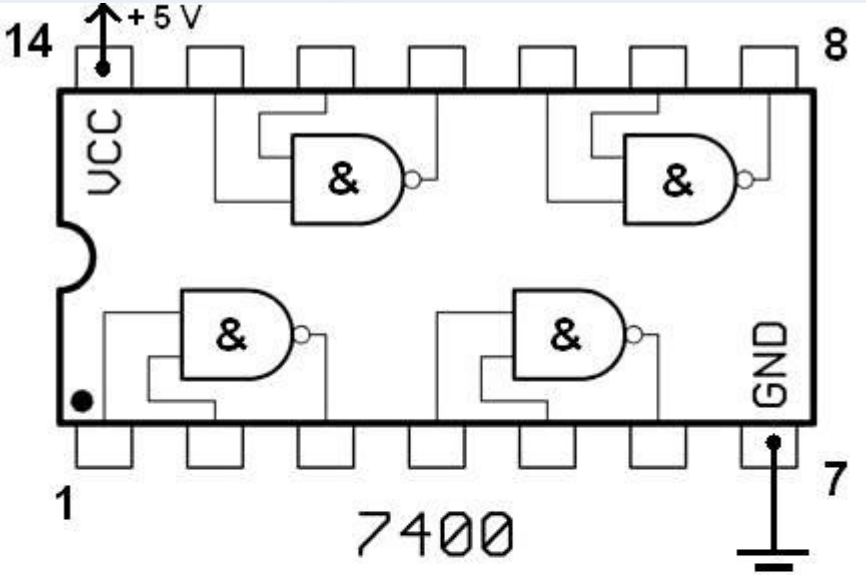
# Планарная технология

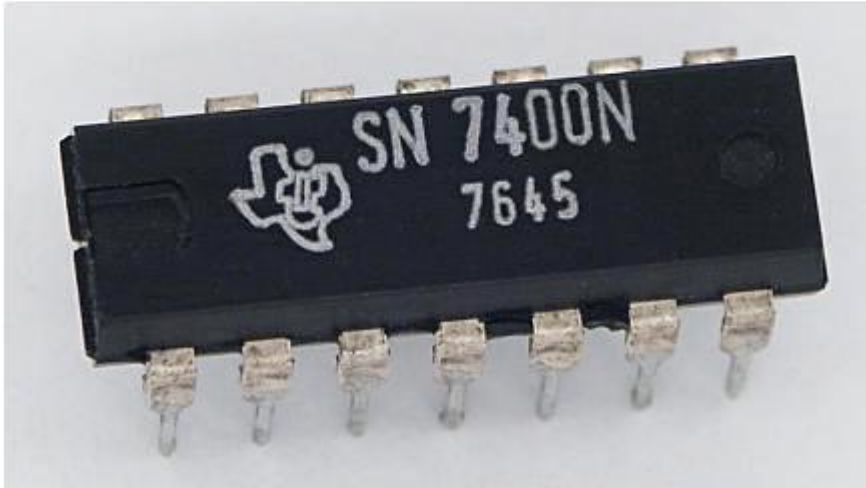


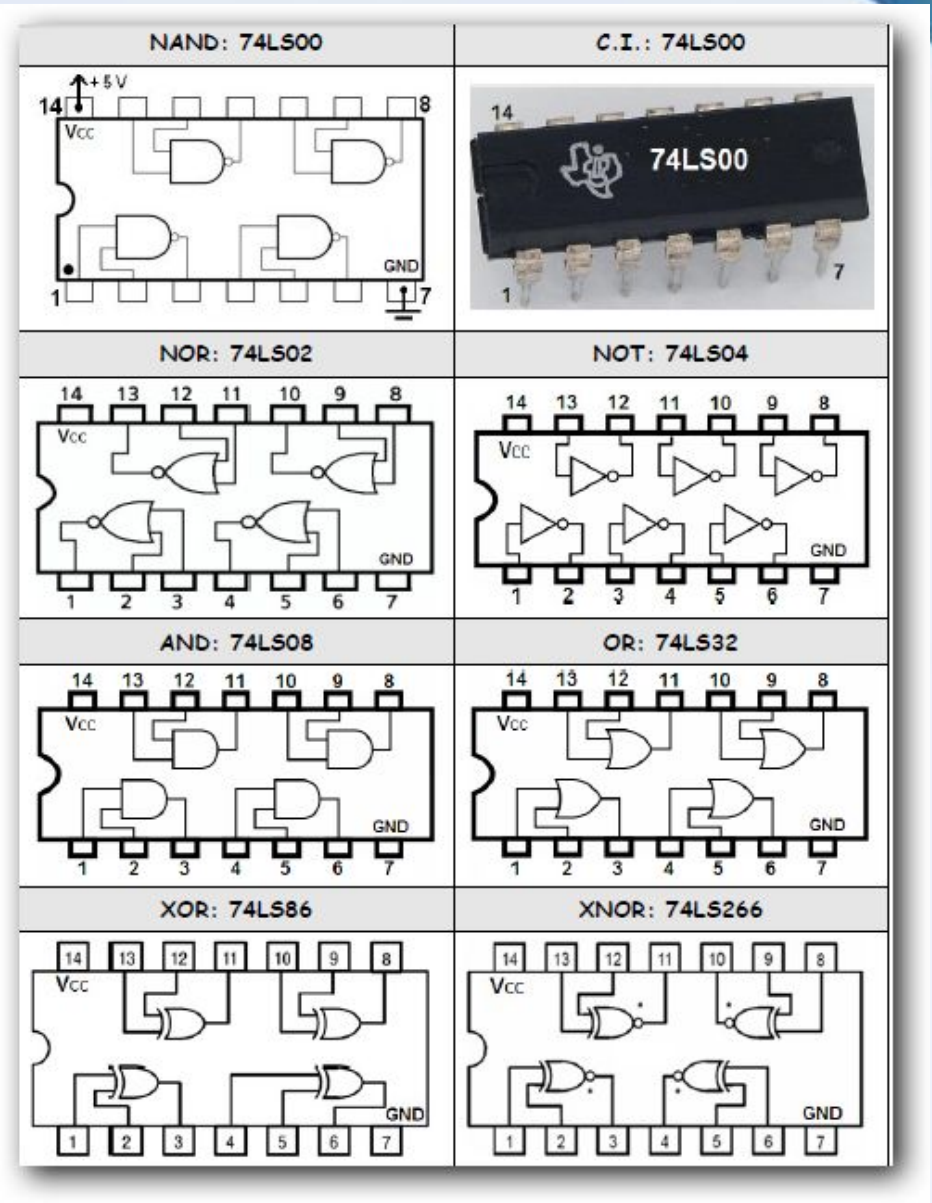


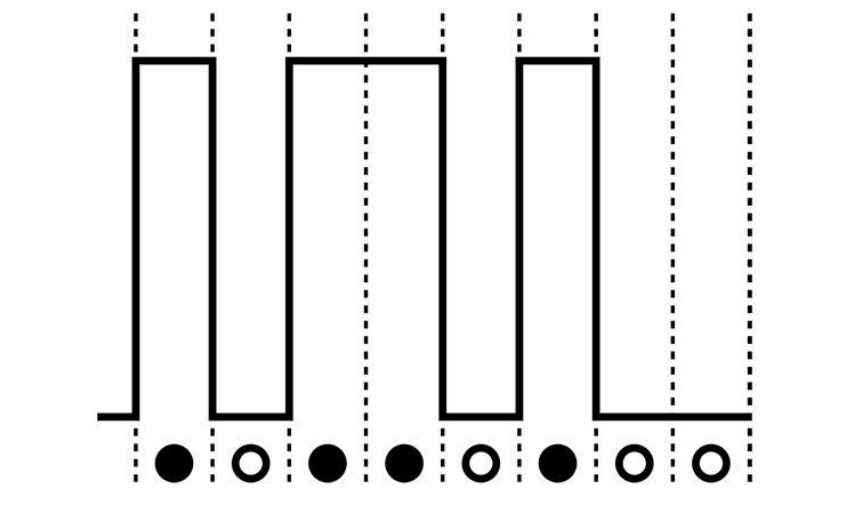
# TI 7400-series

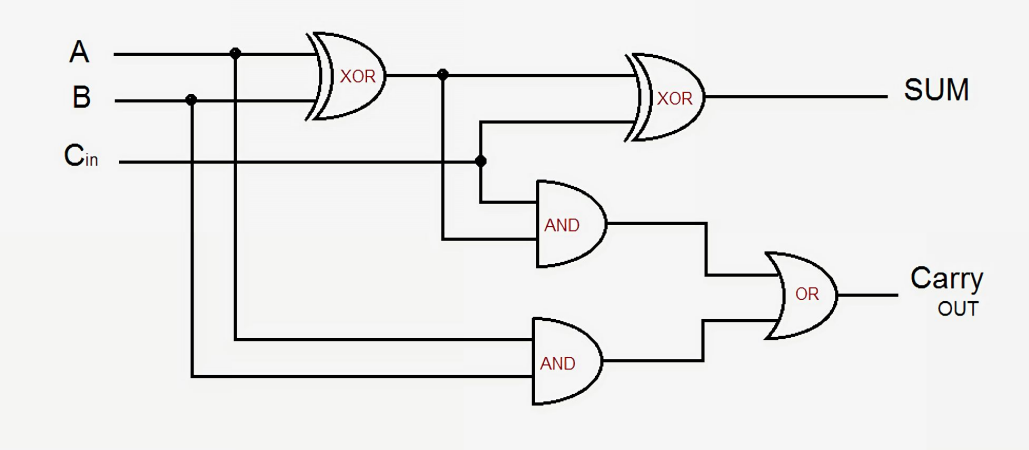


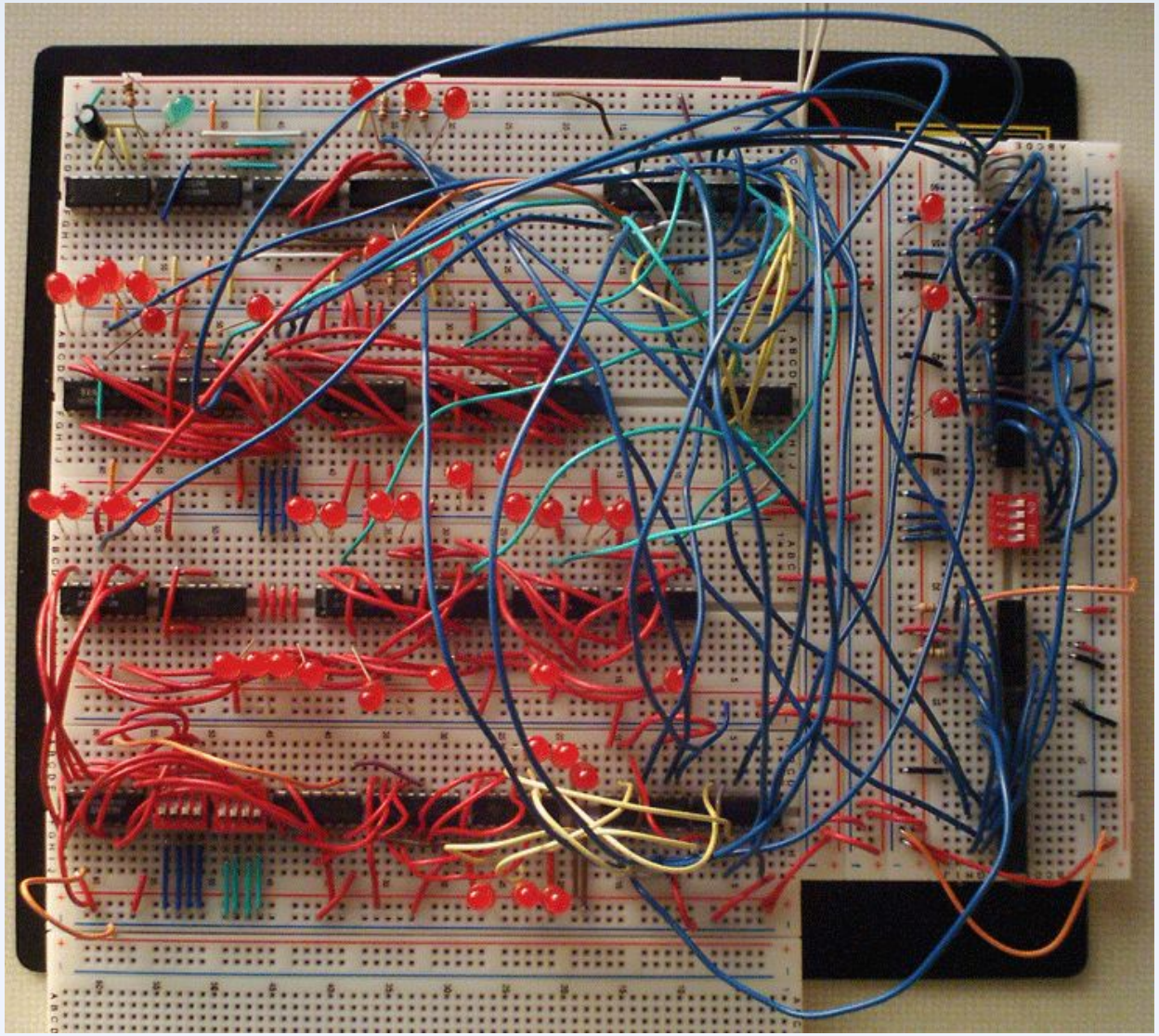



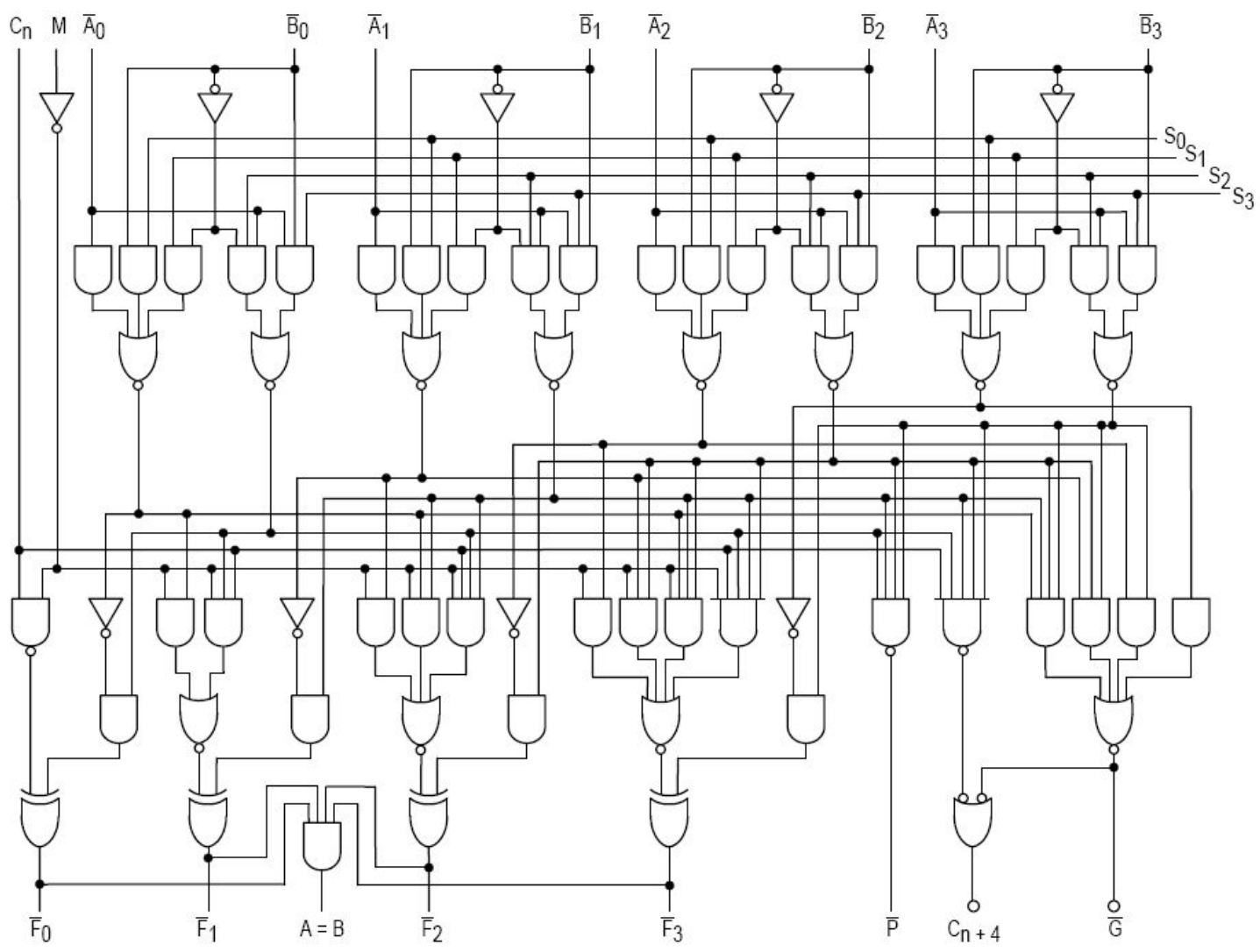



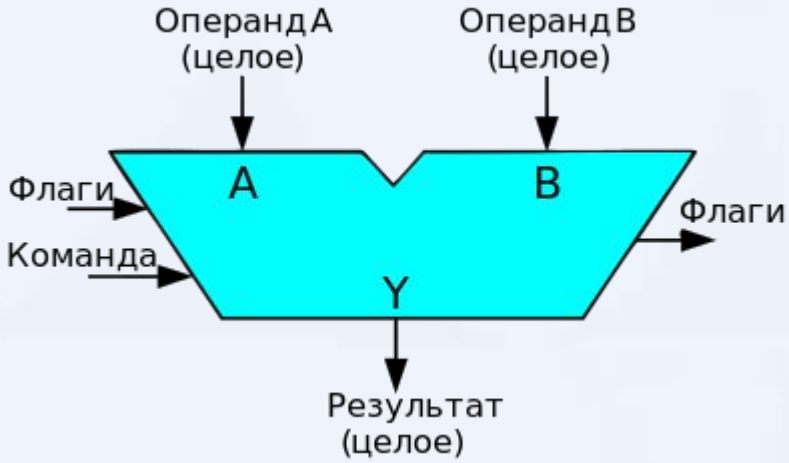





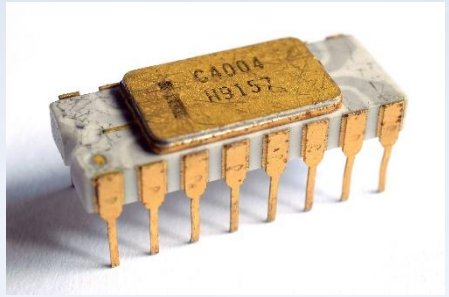

A
B
Cin
XOR
XOR
SUM
AND
OR
Carry
OUT
AND

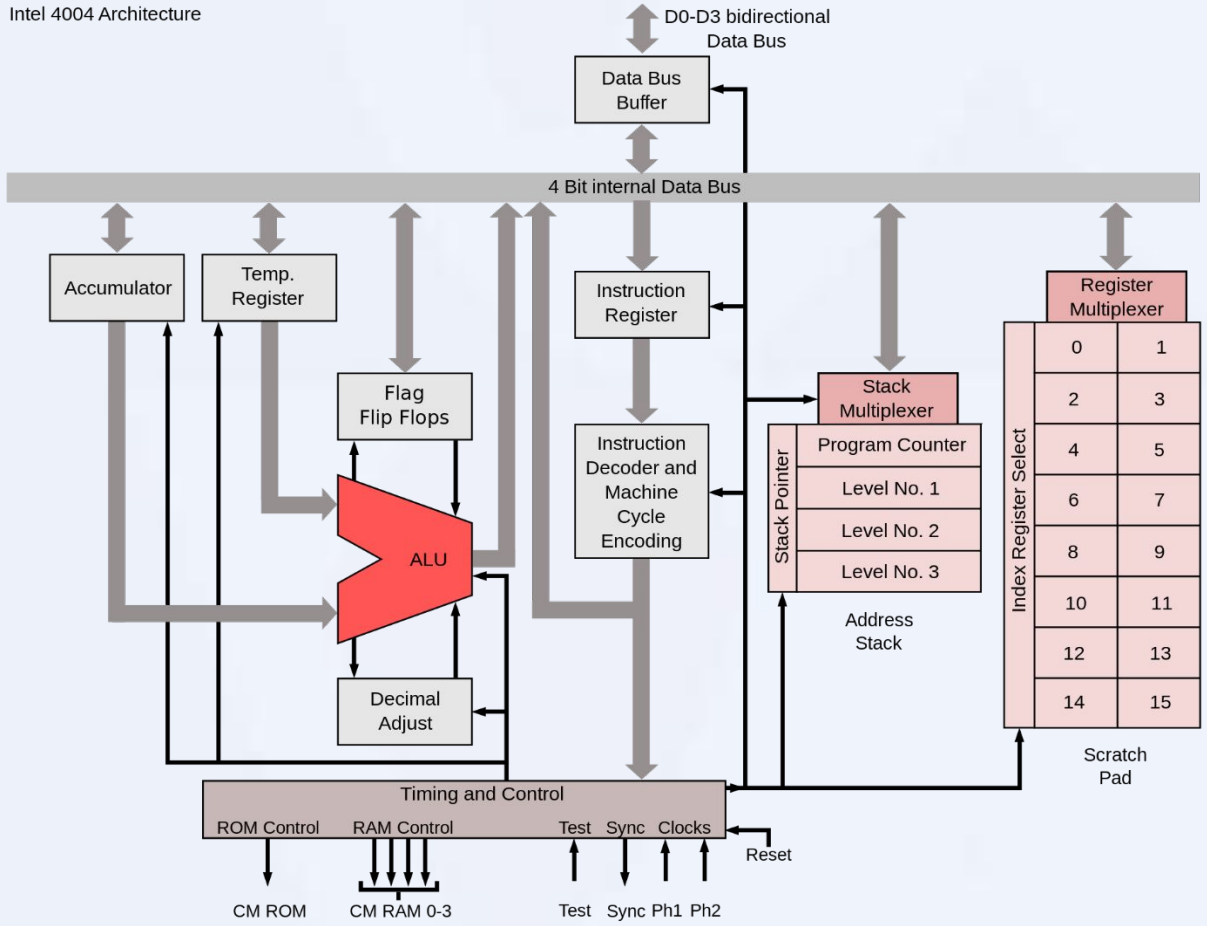


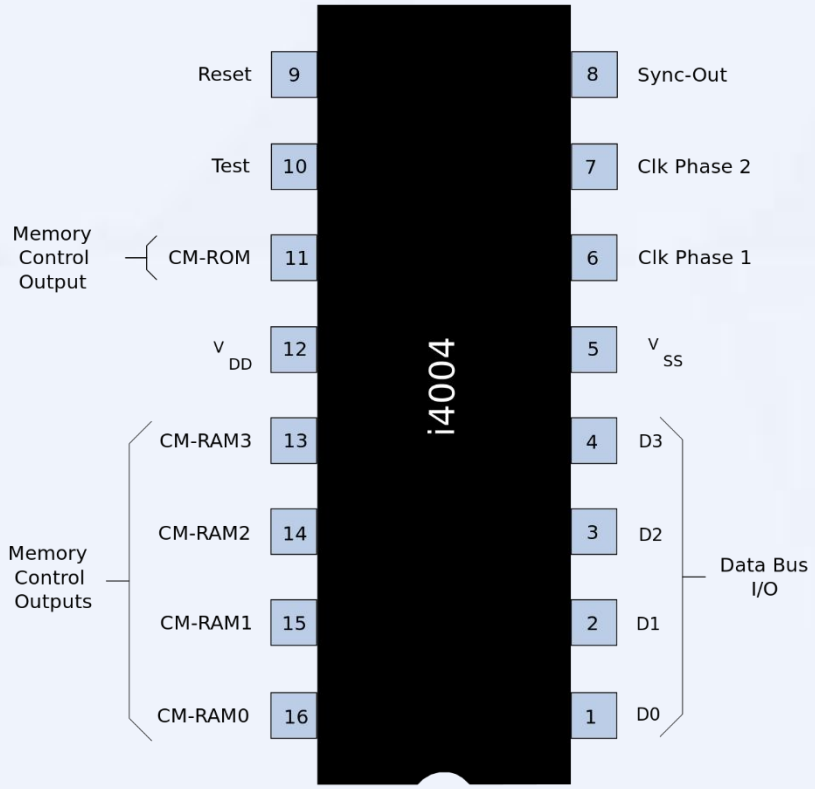

Cn
M
A0
B0
A1
B1
A2
B2
A3
B3
S0
S1
S2
S3
F0
F1
A = B
F2
F3
P
Cn + 4
G

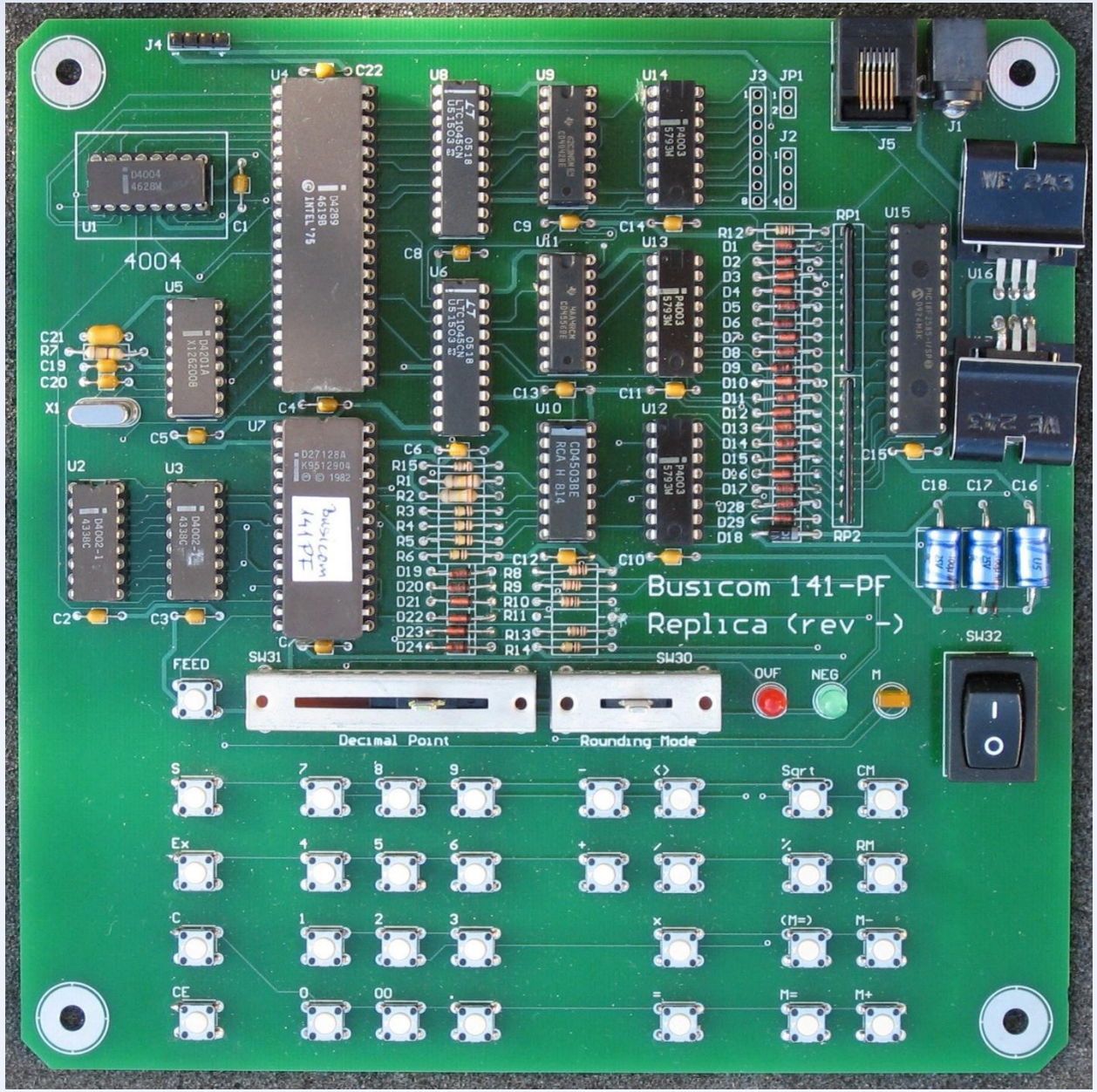

Операнд A
(целое)
Операнд B
(целое)
A
B
Флаги
Команда
Флаги
Y
Результат
(целое)

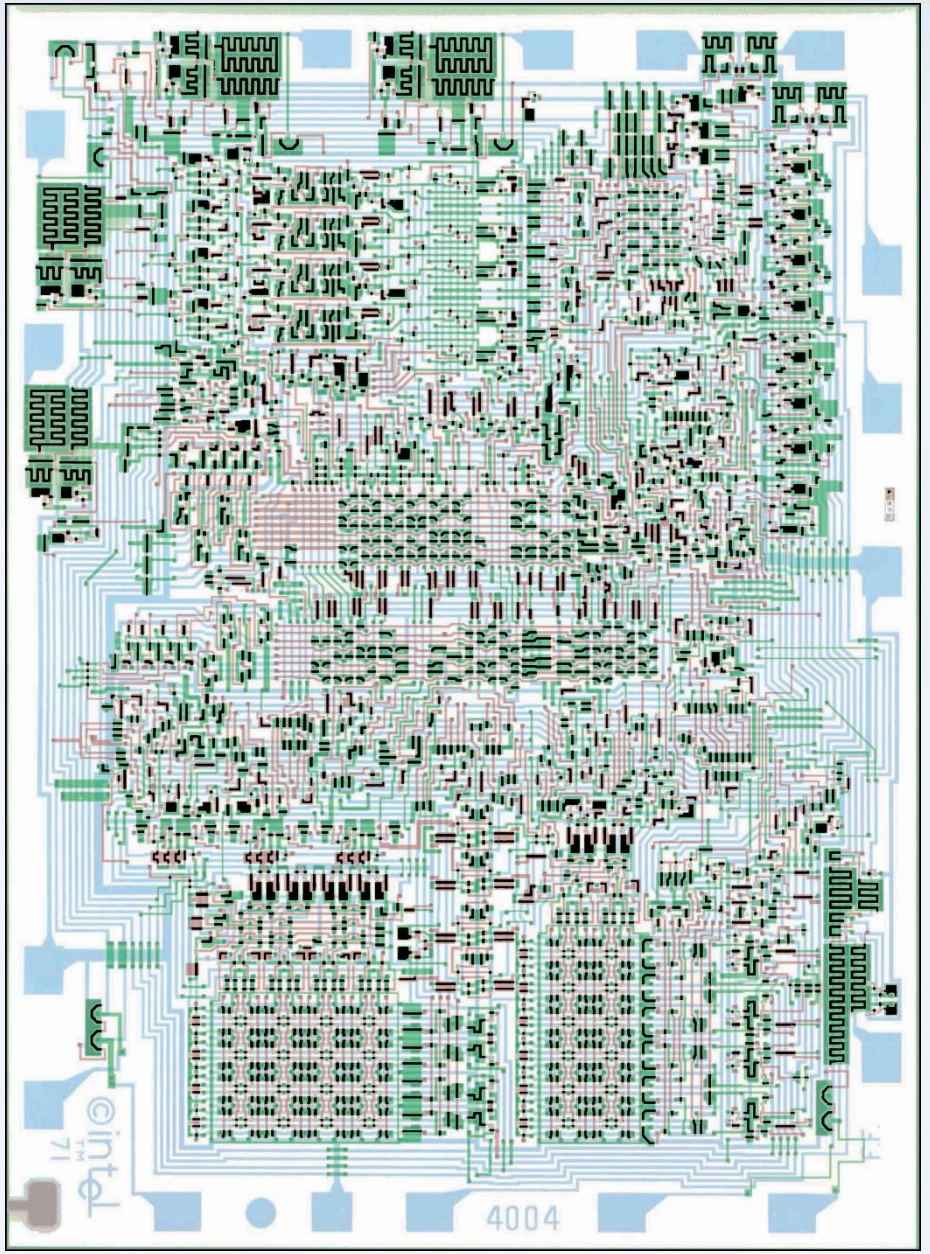
INTEL 4004 (1971) – первый коммерческий 4-битный процессор
2300 транзисторов
Технология 10 мкм
Частота 740 кГц



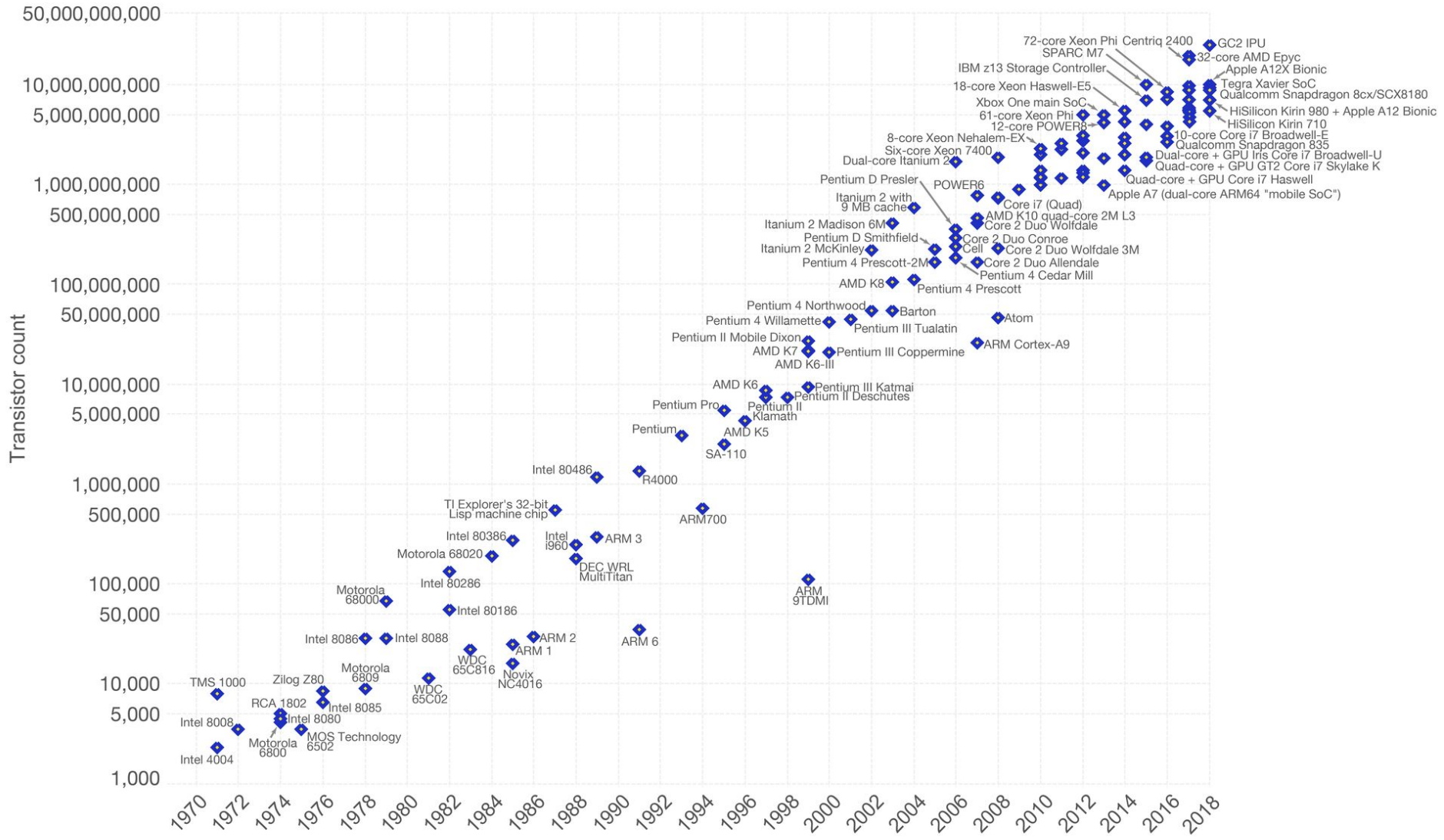




Busicom 141-PF
Replica (rev °-)
4004
FEED
SW31
SW30
Decimal Point
Rounding Mode
OVF
NEG
M
SW32


4004

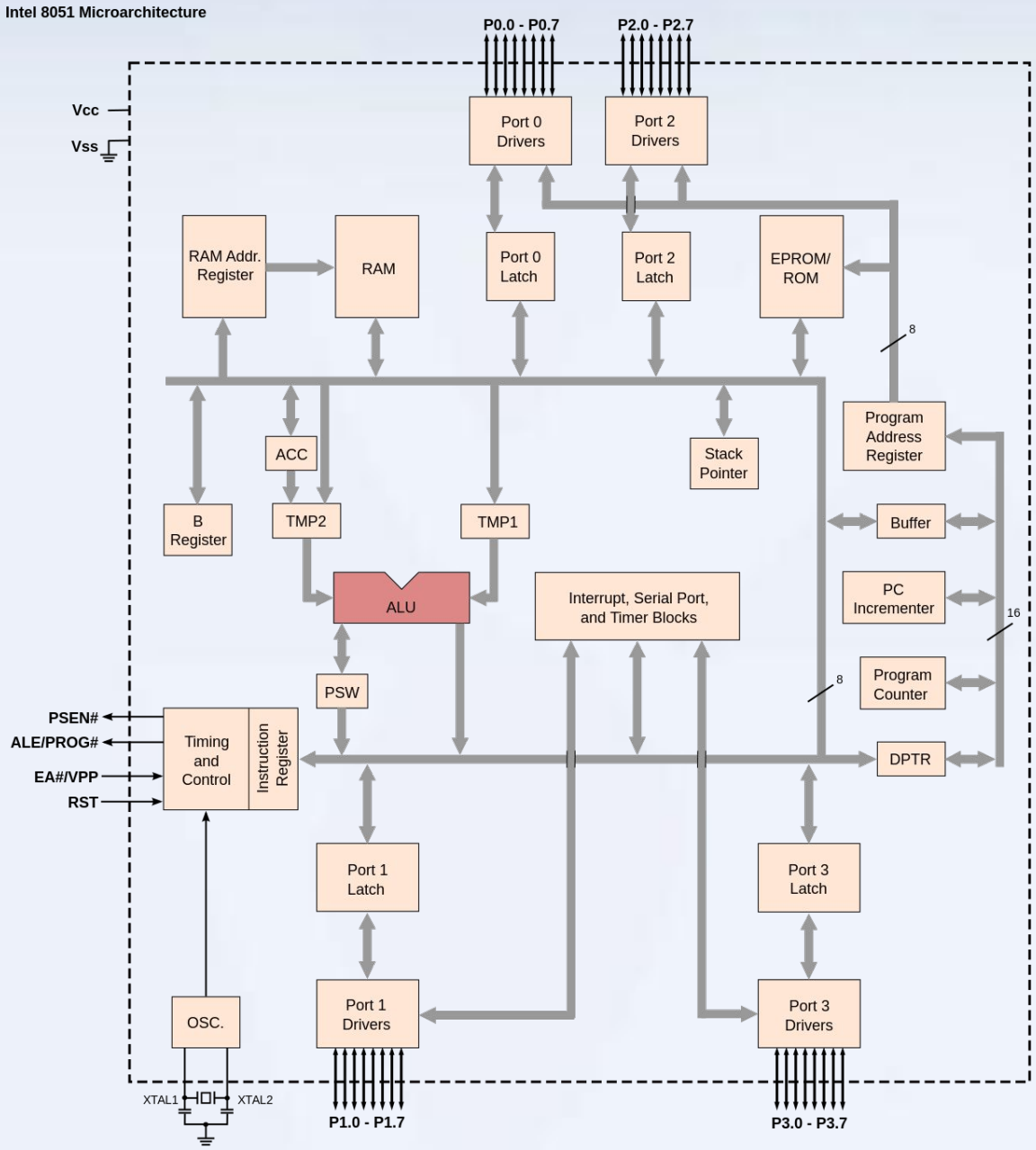
# Moore's Law – The number of transistors on integrated circuit chips (1971-2018)

Moore's law describes the empirical regularity that the number of transistors on integrated circuits doubles approximately every two years. This advancement is important as other aspects of technological progress – such as processing speed or the price of electronic products – are linked to Moore's law.




Data source: Wikipedia (https://en.wikipedia.org/wiki/Transistor_count)
The data visualization is available at OurWorldinData.org. There you find more visualizations and research on this topic.

Licensed under CC-BY-SA by the author Max Roser.



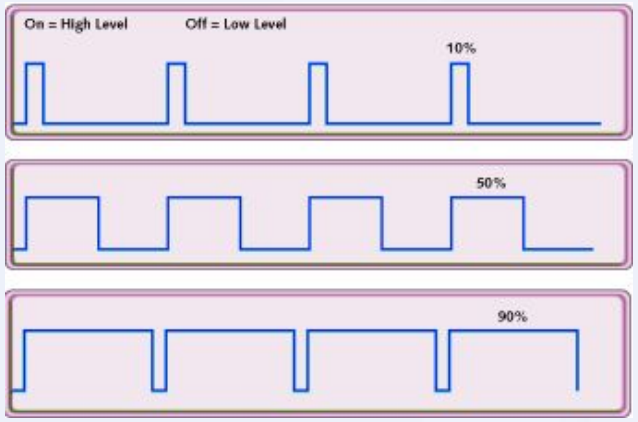

INTEL 8048 (1976-1990) – первый коммерческий 8-битный микроконтроллер

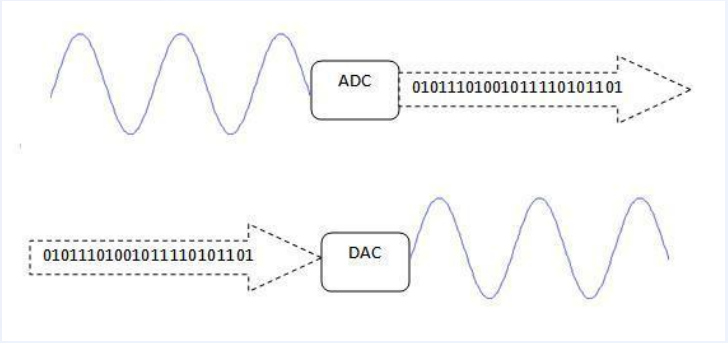
INTEL 8051 (1980- ) – первый коммерческий 8-битный микроконтроллер

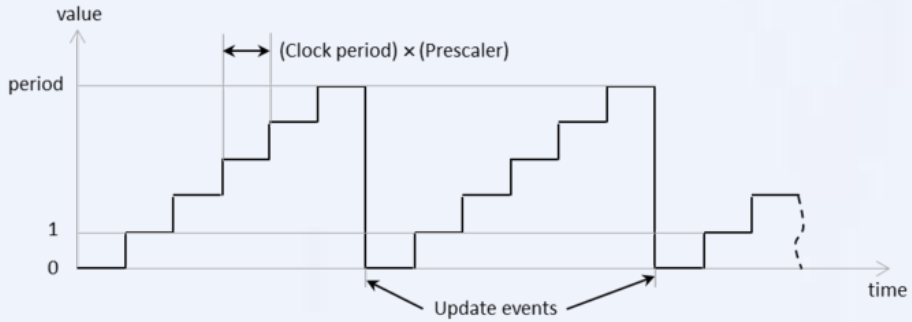
8 битный АЛУ
17 инструкций процессора
ОЗУ 128 байт
ПЗУ 4 КБ
Частота от 12 МГц (1 миллион операций в секунду)

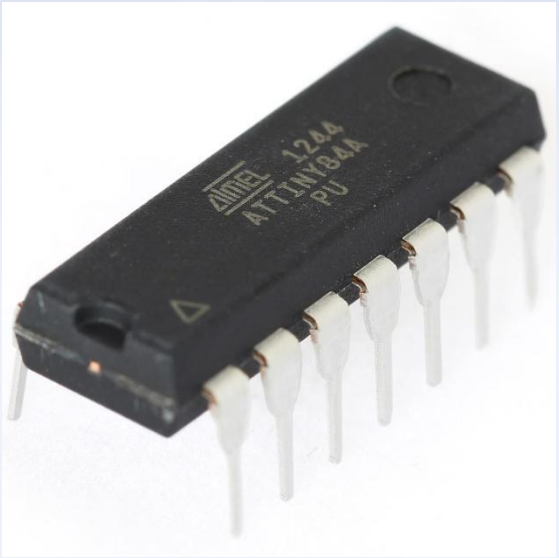
Главные устройства «расширения» возможностей микроконтроллера

- универсальные цифровые порты, которые можно настраивать как на ввод, так и на вывод;
- различные интерфейсы ввода-вывода, такие, как UART, I²C, SPI, CAN, USB, IEEE 1394, Ethernet;
- аналого-цифровые и цифро-аналоговые преобразователи;
- компараторы;
- широтно-импульсные модуляторы (ШИМ-контроллер);
- таймеры;
- контроллеры бесколлекторных двигателей, в том числе шаговых;
- контроллеры дисплеев и клавиатур;
- радиочастотные приемники и передатчики;
- массивы встроенной флеш-памяти;
- встроенные тактовый генератор и сторожевой таймер;

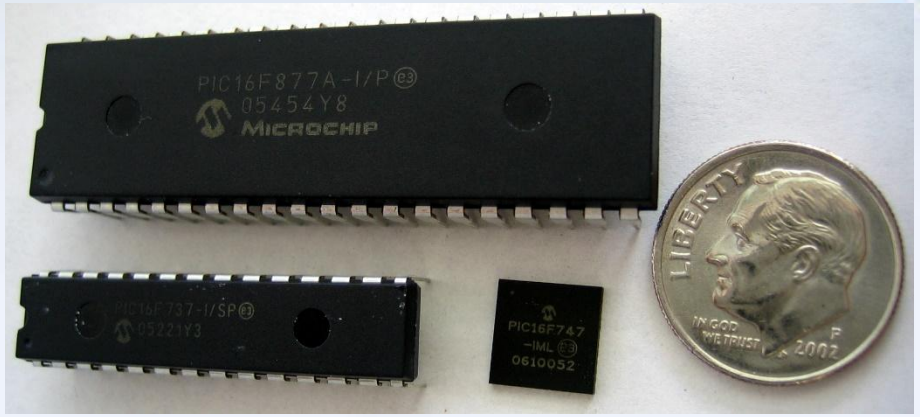


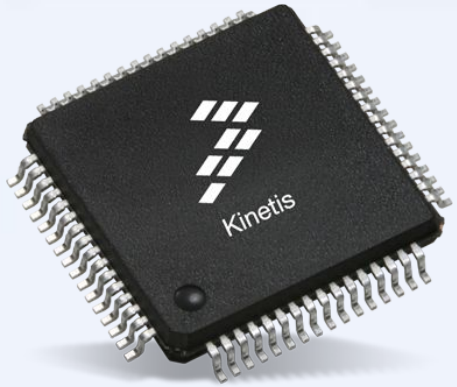



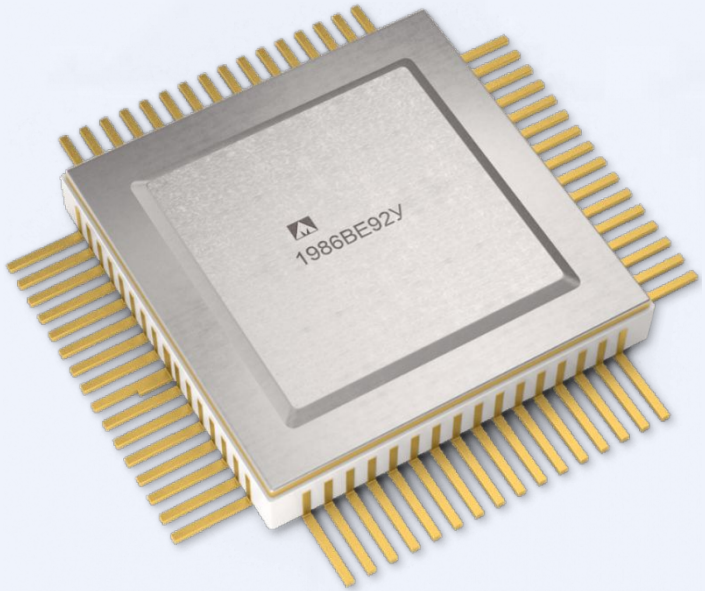

ATTINY84A
PU

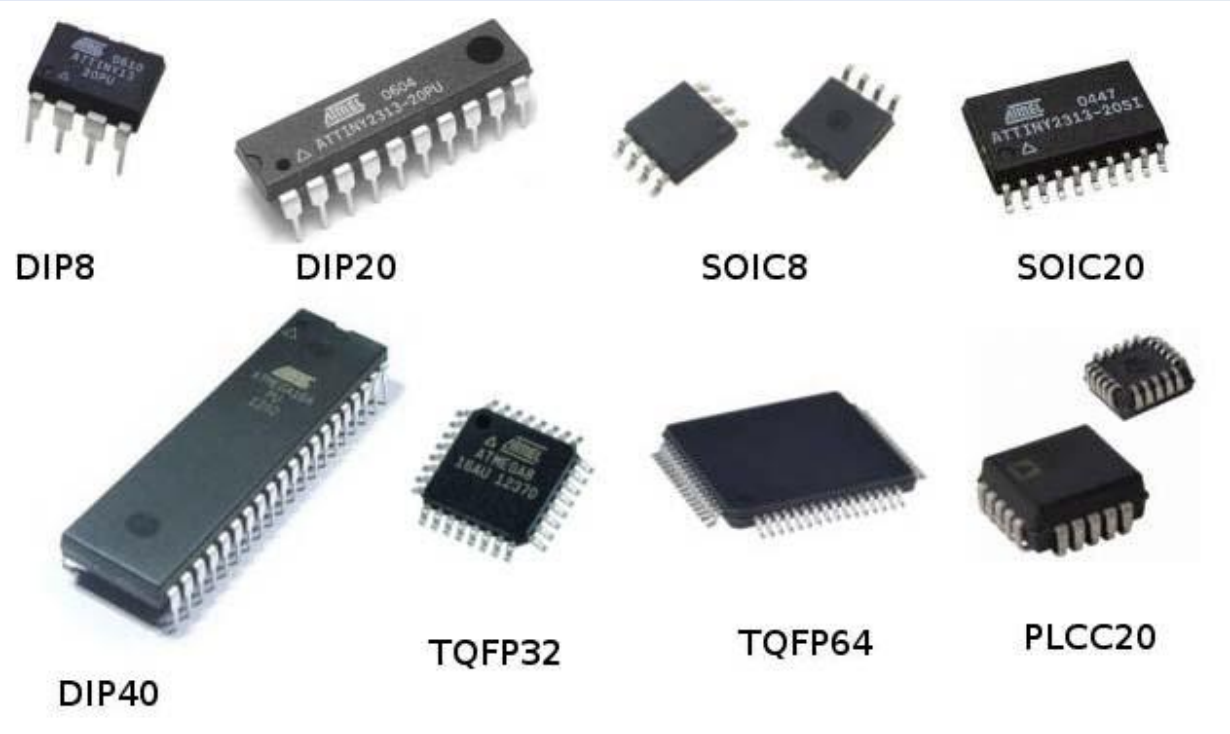
MSP432P401M
Texas Instruments

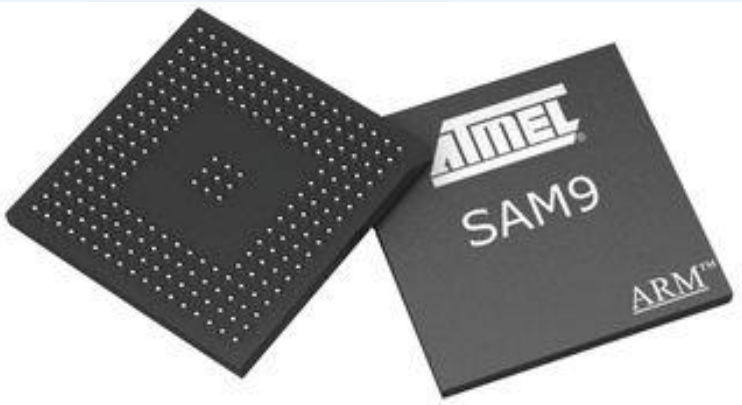

PIC16F877A-I/P
05454Y8
MICROCHIP
PIC16F747
0610052
LIBERTY
IN GOD WE TRUST
2002

STM32
Cortex

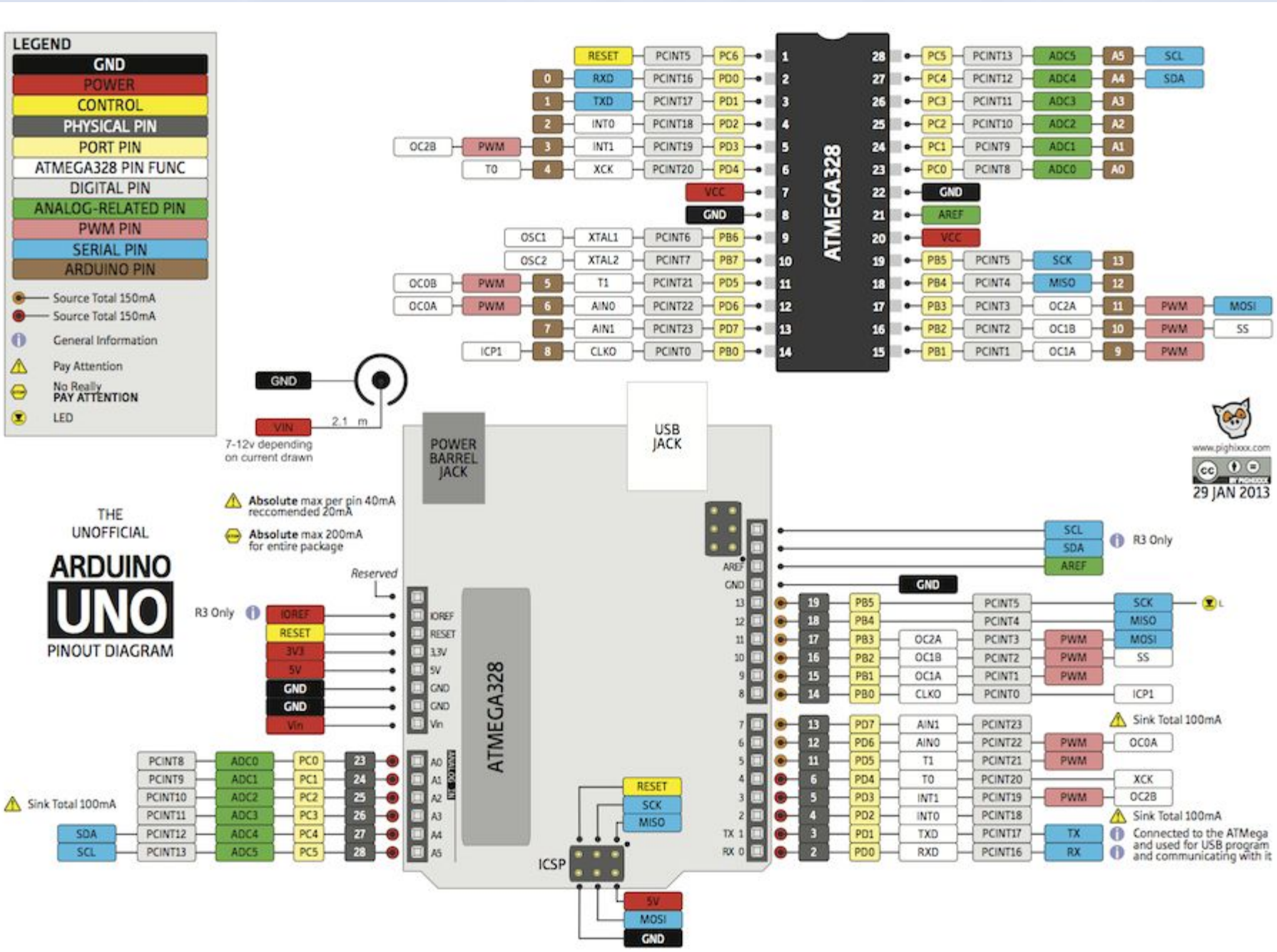

Kinetis

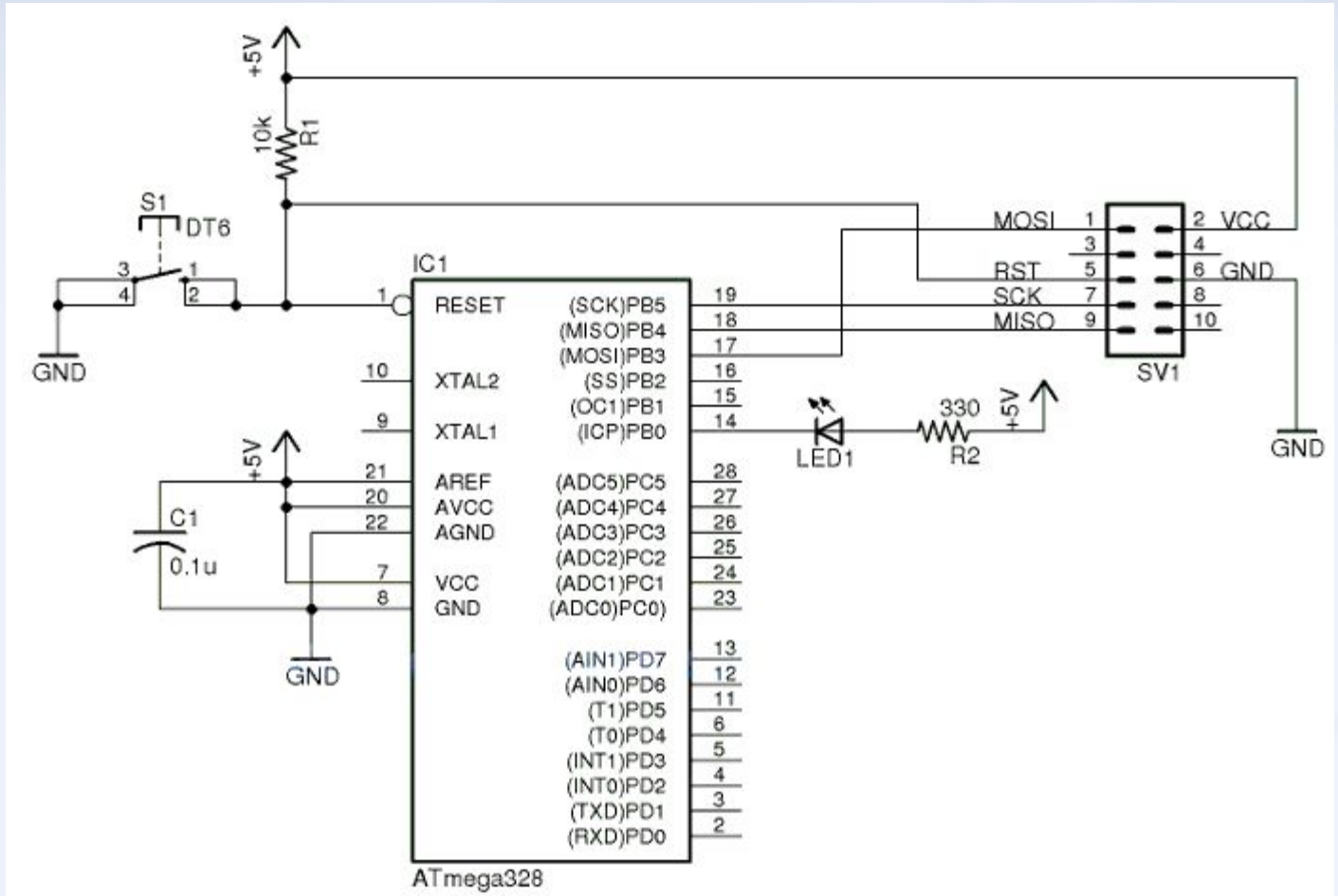

1986BE92y

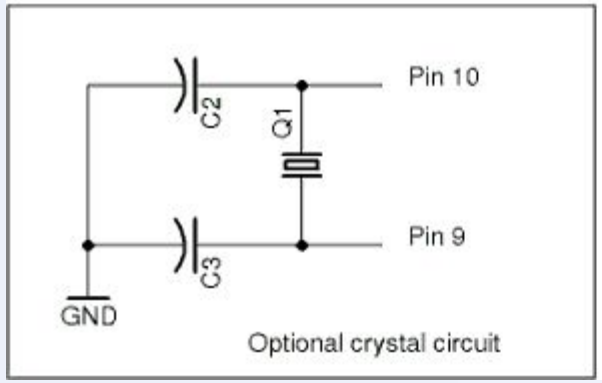

DIP8
DIP20
SOIC8
SOIC20
DIP40
TQFP32
TQFP64
PLCC20

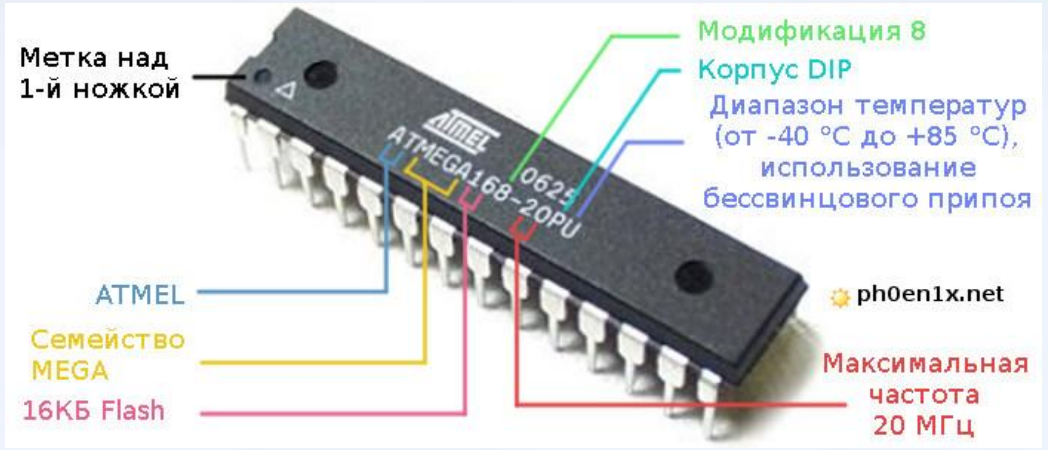

ATMEL
SAM9
ARM™

СДЕЛАНО В СССР
К573РФ5
8701


LEGEND
GND
POWER
CONTROL
PHYSICAL PIN
PORT PIN
ATMEGA328 PIN FUNC
DIGITAL PIN
ANALOG-RELATED PIN
PWM PIN
SERIAL PIN
ARDUINO PIN
Source Total 150mA
Source Total 150mA
General Information
Pay Attention
No Really
PAY ATTENTION
LED
ATMEGA328
RESET PCINT5 PC6 1
0 RXD PCINT16 PD0 2
1 TXD PCINT17 PD1 3
2 INT0 PCINT18 PD2 4
OC2B PWM 3 INT1 PCINT19 PD3 5
T0 4 XCK PCINT20 PD4 6
VCC 7
GND 8
OSC1 XTAL1 PCINT6 PB6 9
OSC2 XTAL2 PCINT7 PB7 10
OC0B PWM 5 T1 PCINT21 PD5 11
OC0A PWM 6 AIN0 PCINT22 PD6 12
7 AIN1 PCINT23 PD7 13
ICP1 8 CLKO PCINT0 PB0 14
28 PC5 PCINT13 ADC5 A5 SCL
27 PC4 PCINT12 ADC4 A4 SDA
26 PC3 PCINT11 ADC3 A3
25 PC2 PCINT10 ADC2 A2
24 PC1 PCINT9 ADC1 A1
23 PC0 PCINT8 ADC0 A0
22 GND
21 AREF
20 VCC
19 PB5 PCINT5 SCK 13
18 PB4 PCINT4 MISO 12
17 PB3 PCINT3 OC2A 11 PWM MOSI
16 PB2 PCINT2 OC1B 10 PWM SS
15 PB1 PCINT1 OC1A 9 PWM
GND
VIN
2.1 m
7-12v depending on current drawn
POWER BARREL JACK
USB JACK
www.pighixxx.com
29 JAN 2013
THE UNOFFICIAL
ARDUINO UNO
PINOUT DIAGRAM
Absolute max per pin 40mA reccomended 20mA
Absolute max 200mA for entire package
Reserved
R3 Only
IOREF
RESET
3V3
5V
GND
GND
Vin
ATMEGA328
IOREF
RESET
3.3V
5V
GND
GND
Vin
A0
A1
A2
A3
A4
A5
ANALOG IN
AREF
GND
13
12
11
10
9
8
7
6
5
4
3
2
TX 1
RX 0
SCL
SDA
AREF
R3 Only
GND
19 PB5 PCINT5 SCK
18 PB4 PCINT4 MISO
17 PB3 OC2A PCINT3 PWM MOSI
16 PB2 OC1B PCINT2 PWM SS
15 PB1 OC1A PCINT1 PWM
14 PB0 CLKO PCINT0 ICP1
L
Sink Total 100mA
13 PD7 AIN1 PCINT23
12 PD6 AIN0 PCINT22 PWM OC0A
11 PD5 T1 PCINT21 PWM
6 PD4 T0 PCINT20 XCK
5 PD3 INT1 PCINT19 PWM OC2B
4 PD2 INT0 PCINT18
3 PD1 TXD PCINT17 TX
2 PD0 RXD PCINT16 RX
Sink Total 100mA
Connected to the ATMega and used for USB program and communicating with it
Sink Total 100mA
PCINT8 ADC0 PC0 23
PCINT9 ADC1 PC1 24
PCINT10 ADC2 PC2 25
PCINT11 ADC3 PC3 26
SDA PCINT12 ADC4 PC4 27
SCL PCINT13 ADC5 PC5 28
ICSP
RESET
SCK
MISO
5V
MOSI
GND

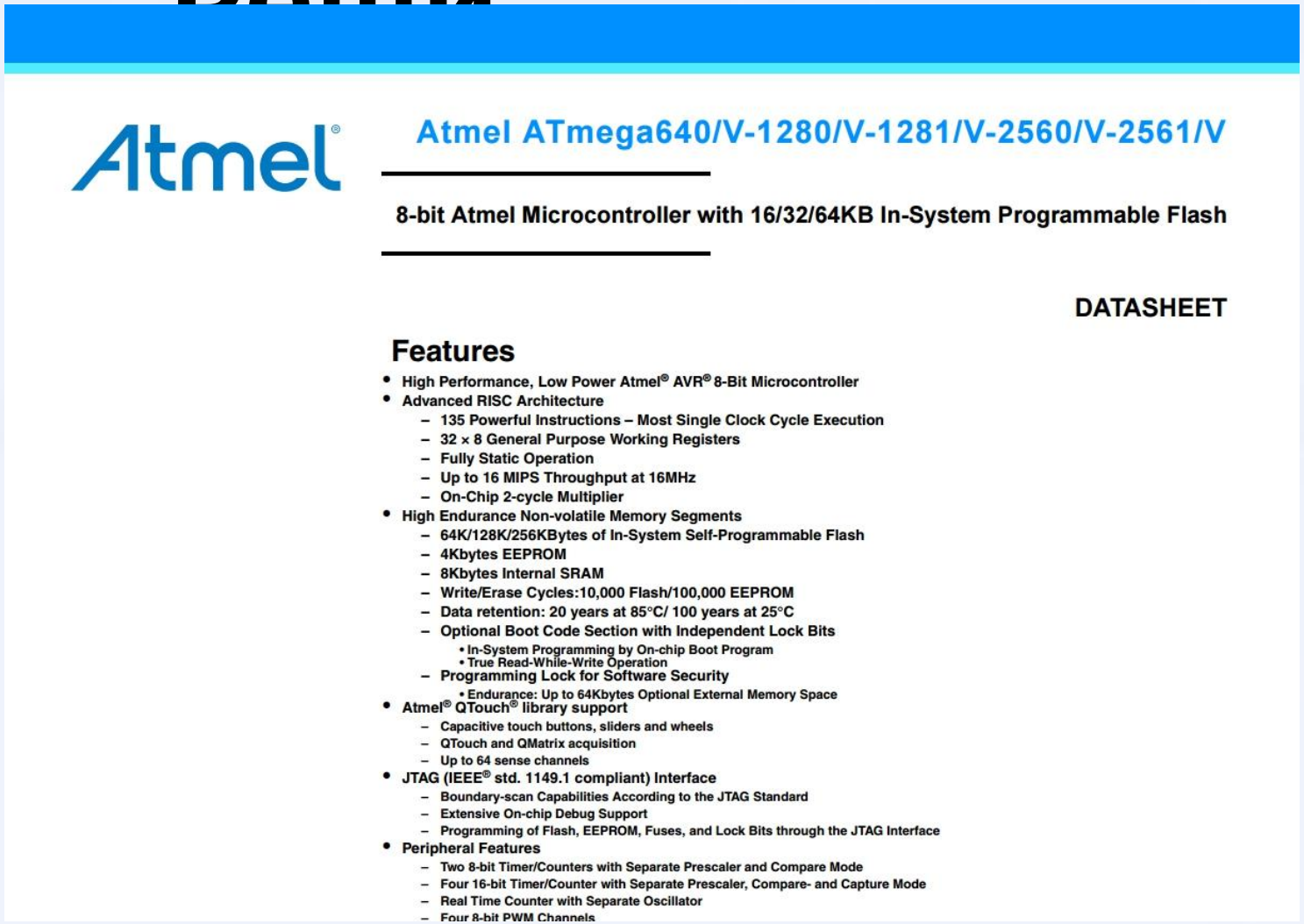

+5V
10k
R1
S1
DT6
GND
IC1
RESET
XTAL2
XTAL1
AREF
AVCC
AGND
VCC
GND
(SCK)PB5
(MISO)PB4
(MOSI)PB3
(SS)PB2
(OC1)PB1
(ICP)PB0
(ADC5)PC5
(ADC4)PC4
(ADC3)PC3
(ADC2)PC2
(ADC1)PC1
(ADC0)PC0
(AIN1)PD7
(AIN0)PD6
(T1)PD5
(T0)PD4
(INT1)PD3
(INT0)PD2
(TXD)PD1
(RXD)PD0
ATmega328
C1
0.1u
MOSI
RST
SCK
MISO
VCC
GND
SV1
LED1
330
R2


Pin 10
C2
Q1
Pin 9
C3
GND
Optional crystal circuit


Метка над
1-й ножкой
Модификация 8
Корпус DIP
Диапазон температур
(от -40 °C до +85 °C),
использование
бессвинцового припоя
ATMEL
Семейство
MEGA
16КБ Flash
Максимальная
частота
20 МГц
ATMEL
ATMEGA168-20PU
0625
ph0en1x.net

# Две самые необходимые вещи

Datasheet



Atmel

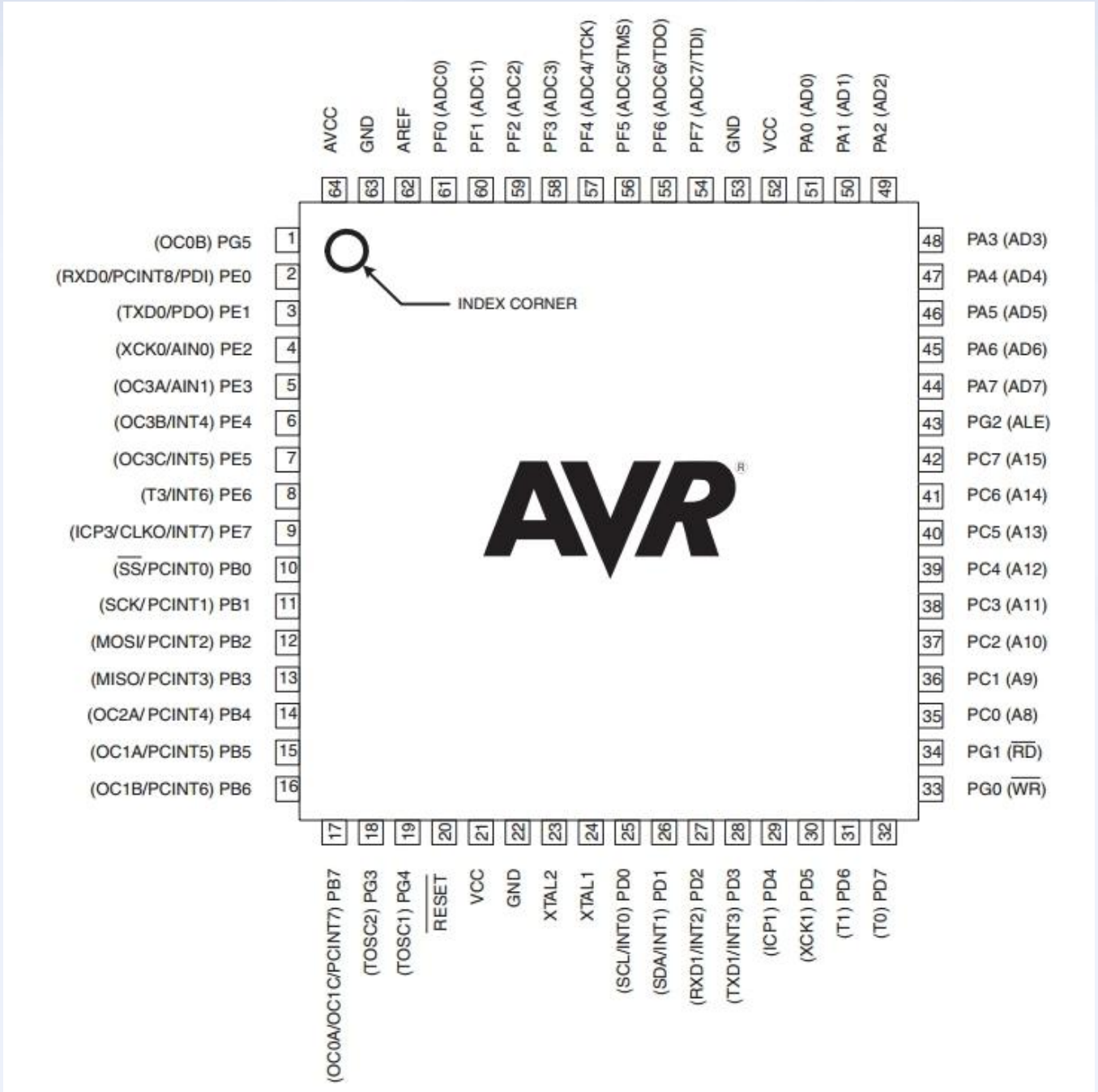
Atmel ATmega640/V-1280/V-1281/V-2560/V-2561/V

8-bit Atmel Microcontroller with 16/32/64KB In-System Programmable Flash

DATASHEET

Features

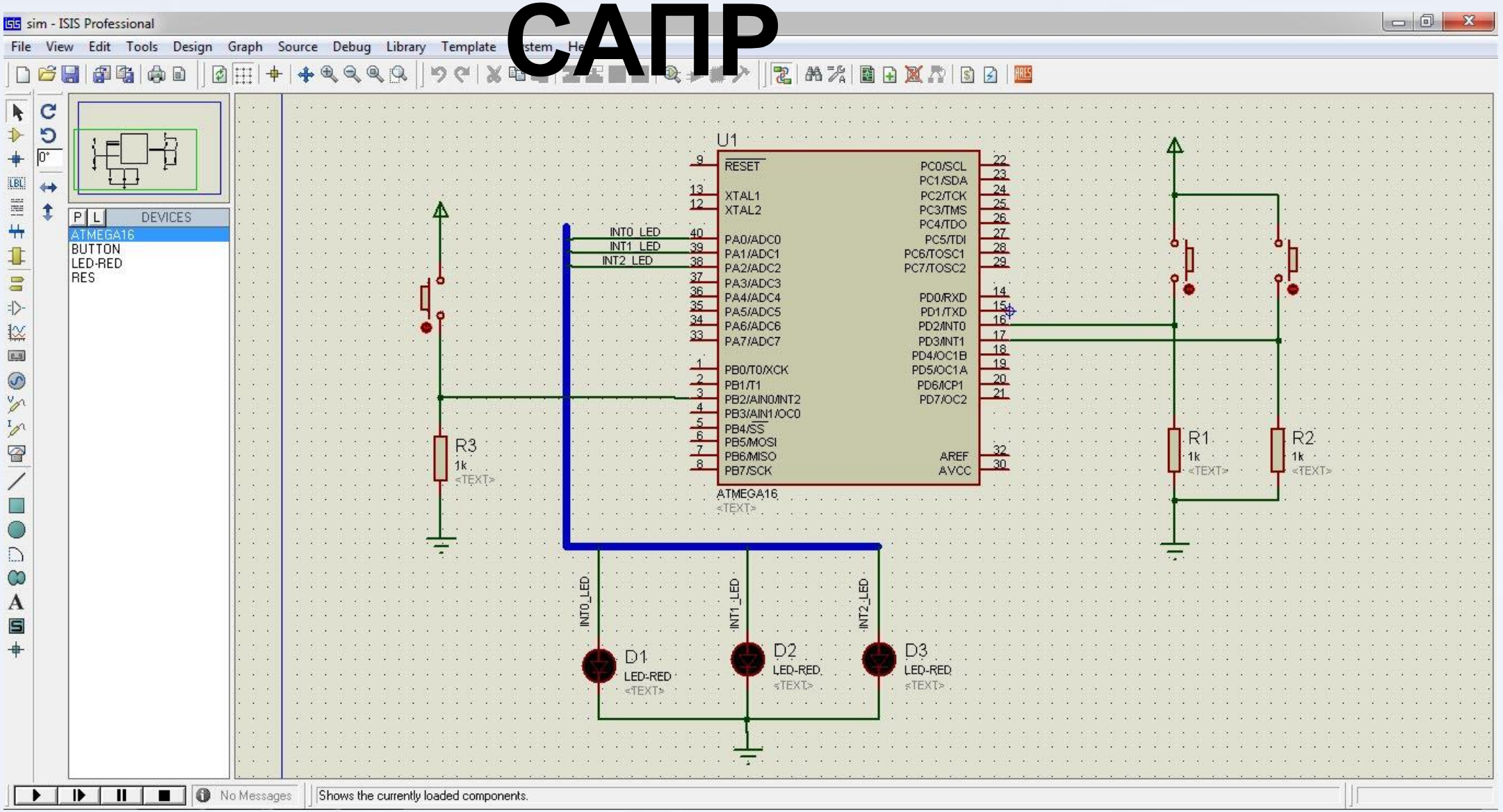
- High Performance, Low Power Atmel® AVR® 8-Bit Microcontroller
- Advanced RISC Architecture
  - 135 Powerful Instructions – Most Single Clock Cycle Execution
  - 32 × 8 General Purpose Working Registers
  - Fully Static Operation
  - Up to 16 MIPS Throughput at 16MHz
  - On-Chip 2-cycle Multiplier
- High Endurance Non-volatile Memory Segments
  - 64K/128K/256KBytes of In-System Self-Programmable Flash
  - 4Kbytes EEPROM
  - 8Kbytes Internal SRAM
  - Write/Erase Cycles:10,000 Flash/100,000 EEPROM
  - Data retention: 20 years at 85°C/ 100 years at 25°C
  - Optional Boot Code Section with Independent Lock Bits
    - In-System Programming by On-chip Boot Program
    - True Read-While-Write Operation
  - Programming Lock for Software Security
    - Endurance: Up to 64Kbytes Optional External Memory Space
- Atmel® QTouch® library support
  - Capacitive touch buttons, sliders and wheels
  - QTouch and QMatrix acquisition
  - Up to 64 sense channels
- JTAG (IEEE® std. 1149.1 compliant) Interface
  - Boundary-scan Capabilities According to the JTAG Standard
  - Extensive On-chip Debug Support
  - Programming of Flash, EEPROM, Fuses, and Lock Bits through the JTAG Interface
- Peripheral Features
  - Two 8-bit Timer/Counters with Separate Prescaler and Compare Mode
  - Four 16-bit Timer/Counter with Separate Prescaler, Compare- and Capture Mode
  - Real Time Counter with Separate Oscillator
  - Four 8-bit PWM Channels

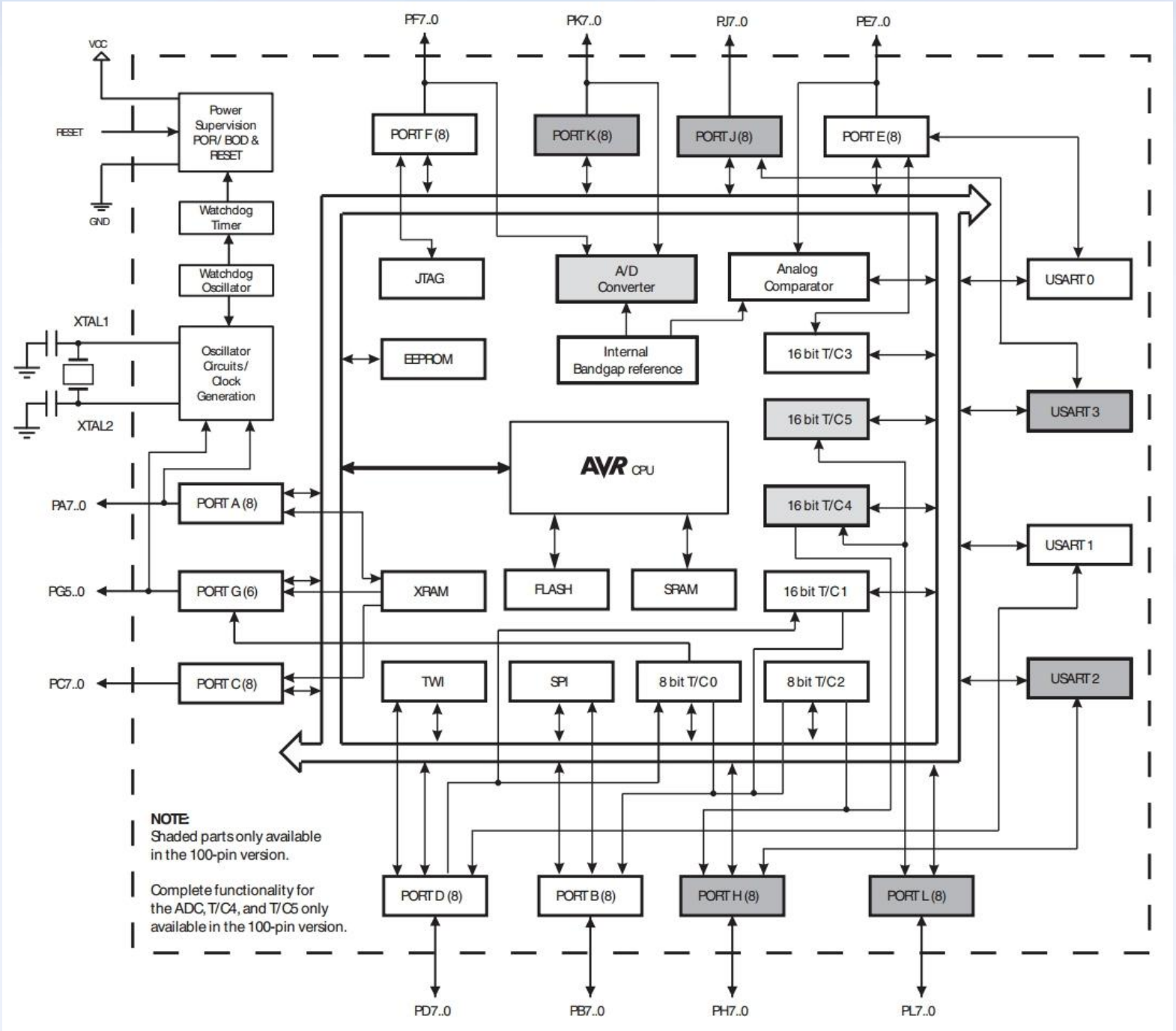



**Информация для «схемотехника»**

**Расположение ножек по их техническому назначению**

# Пример изображения МК в САПР





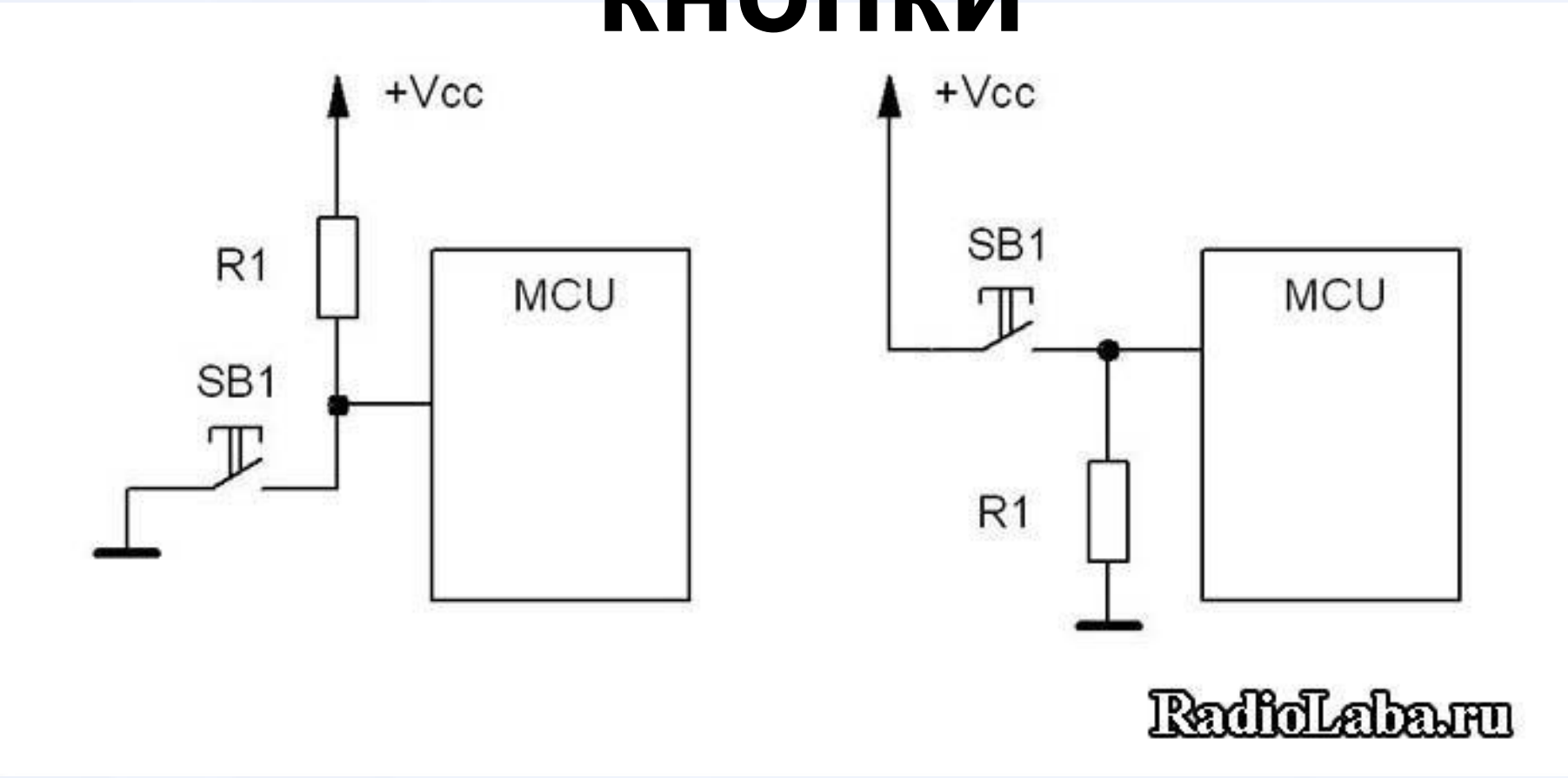

**«Блочность» контроллера**

**Состав микроконтроллера с точки зрения аппаратных устройств**

# Первая программа на AVR

```
#include <io.h>
#include <delay.h> //Подключаем библиотеку для задержки

void main(void)
{
DDRB.7  = 1;  //Записываем в 7-й бит регистра DDRB единицу
              //инициализируем ножку, как выход

PORTB.7 = 0;  //Записываем в 7-й бит регистра PORTB ноль
              //устанавливаем нолевое значение на выходе
while (1) //Бесконечный цикл
    {
    PORTB.7 = ~PORTB.7; // Инверсия 7-го бита
                        // меняем значение в регистре выходного состояния
    delay_ms(500); //Задержка 500мс
    }
}
```

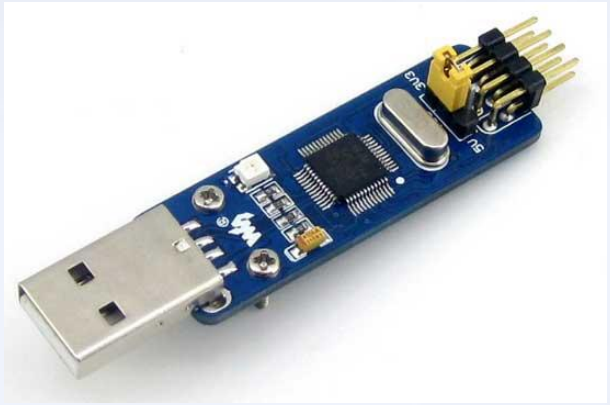
# Варианты подключения кнопки

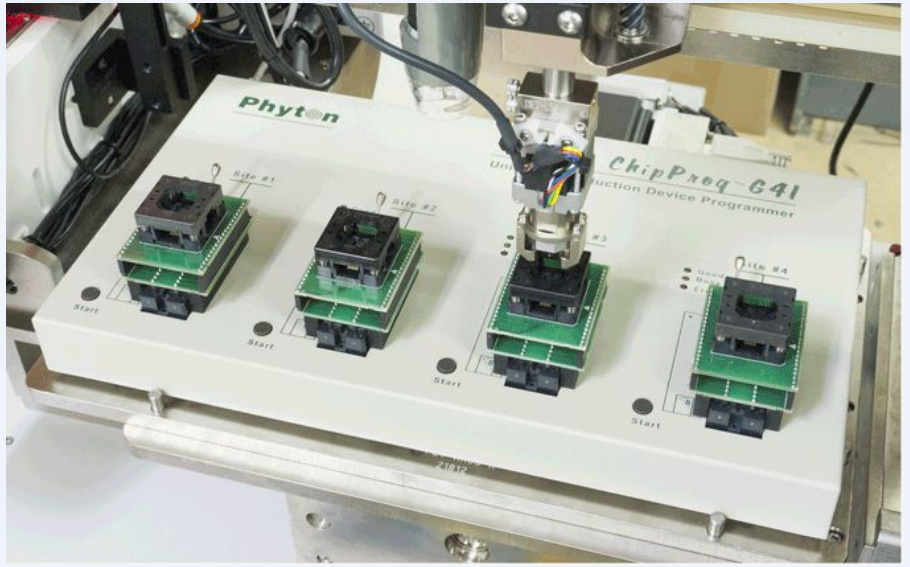


# Реализация подключения кнопки

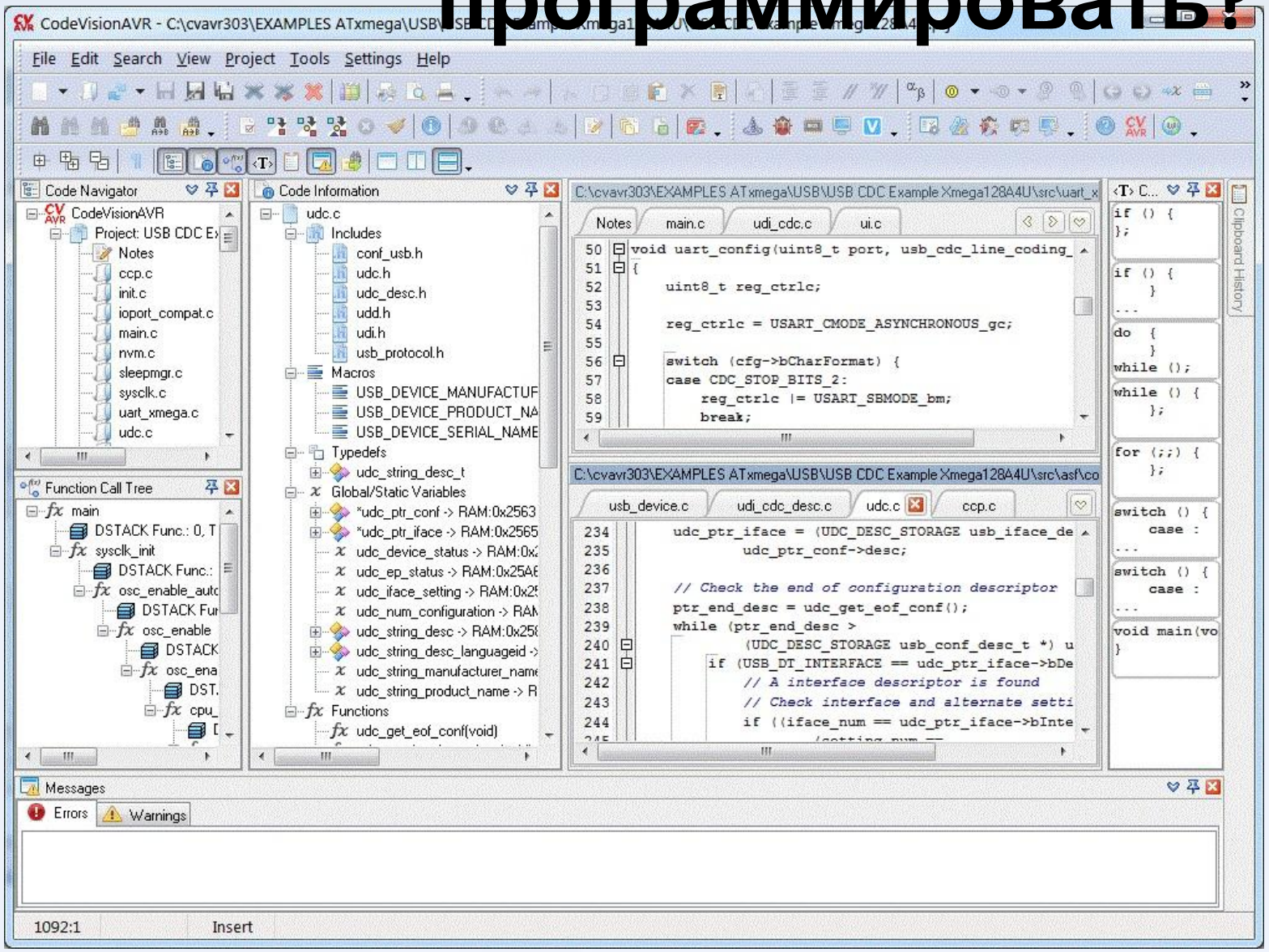
```
#include <io.h>
#include <delay.h> //Подключаем библиотеку для задержки

void main(void)
{
DDRB = 0b10000000;  //Записываем в 7-й бит регистра DDRB единицу
                    //инициализируем ножку, как выход
                    //все остальные ножки порта- входы

PORTB = 0;  //Записываем в 7-й бит регистра PORTB ноль
            //устанавливаем нолевое значение на выходе
while (1) //Бесконечный цикл
    {
        DDRB.7 = PINB.6; //Записываем в 7-й бит состояние из 6-го бита
    }
}
```

# Как программируются («прошиваются») контроллеры?

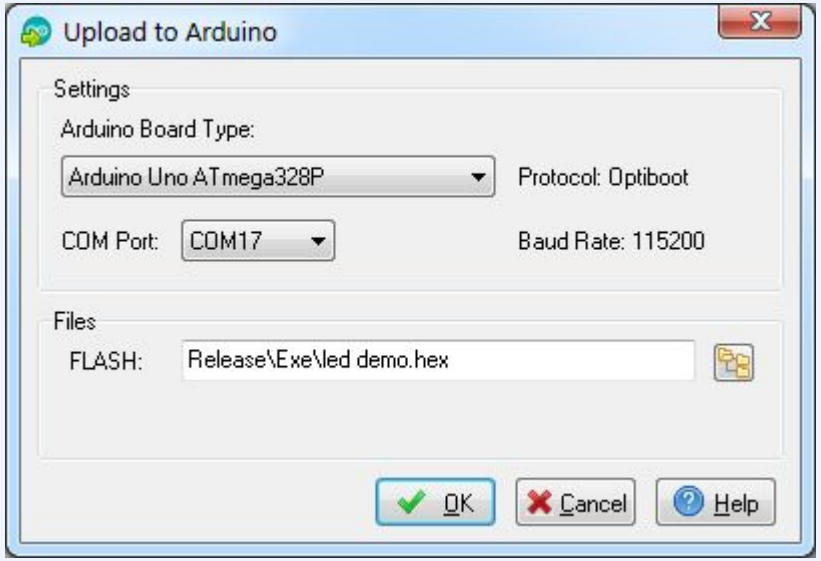


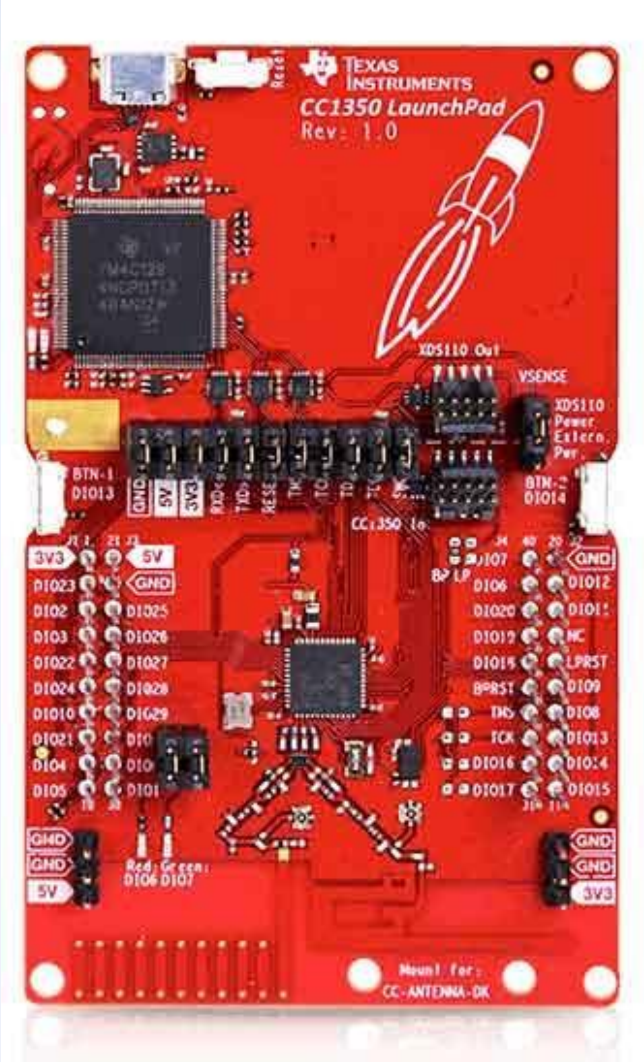
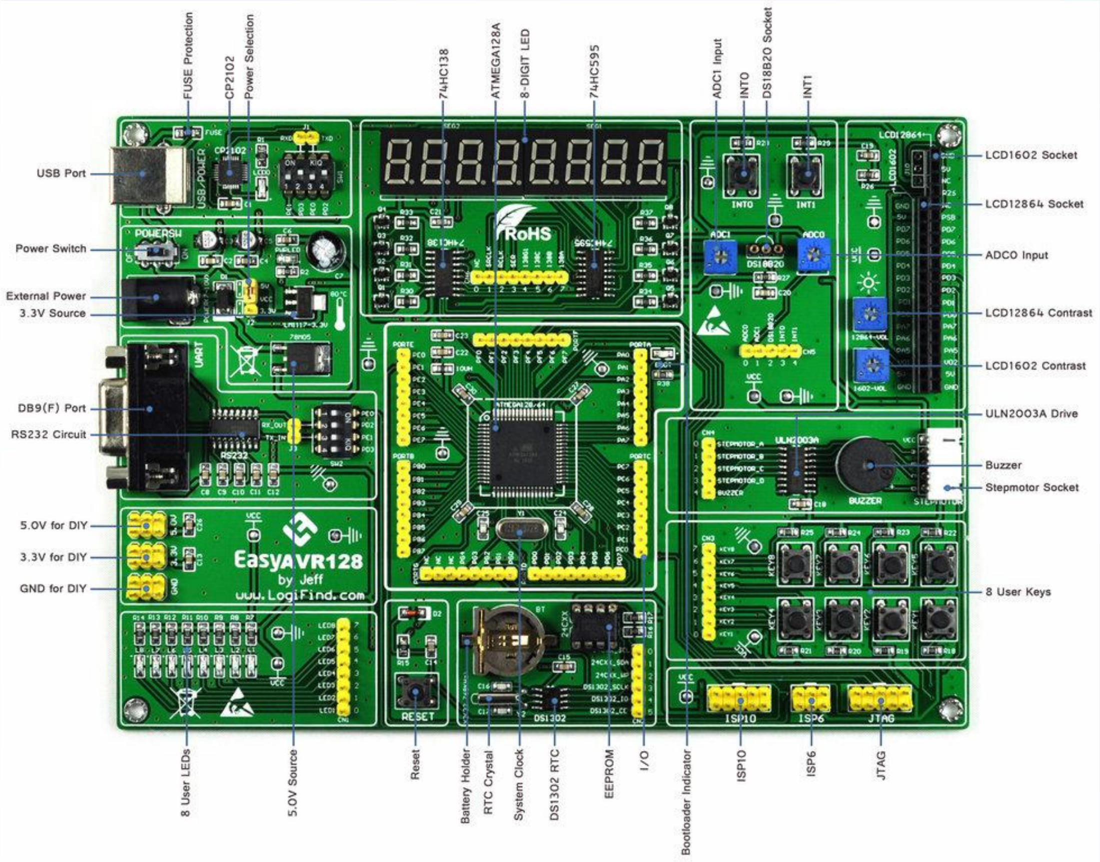


# Что делать если хочется программировать?




http://www.hpinfotech.ro
CodeVisionAVR



MB997A
SWD
ST-LINK
DISCOVERY
www.st.com/stm32f4-discovery
8.000NIL
STM32F4
User
Reset

Texas Instruments
CC1350 LaunchPad
Rev: 1.0
XDS110 Out
VSENSE
XDS110 Power
BTN-1
DIO13
BTN-2
DIO14
Red: Green:
DIO6 DIO7
Mount for:
CC-ANTENNA-DK

FUSE Protection
CP2102
Power Selection
74HC138
ATMEGA128A
8-DIGIT LED
74HC595
ADC1 Input
INT0
DS18B20 Socket
INT1
USB Port
Power Switch
External Power
3.3V Source
DB9(F) Port
RS232 Circuit
5.0V for DIY
3.3V for DIY
GND for DIY
LCD1602 Socket
LCD12864 Socket
ADC0 Input
LCD12864 Contrast
LCD1602 Contrast
ULN2003A Drive
Buzzer
Stepmotor Socket
8 User Keys
EasyAVR128
by Jeff
www.LogiFind.com
8 User LEDs
5.0V Source
Reset
Battery Holder
RTC Crystal
System Clock
DS1302 RTC
EEPROM
I/O
Bootloader Indicator
ISP10
ISP6
JTAG

# СПАСИБО ЗА ВНИМАНИЕ

(Введение в программирование микроконтроллеров)

Мушников Игорь