

Arbeitskreis Hardware

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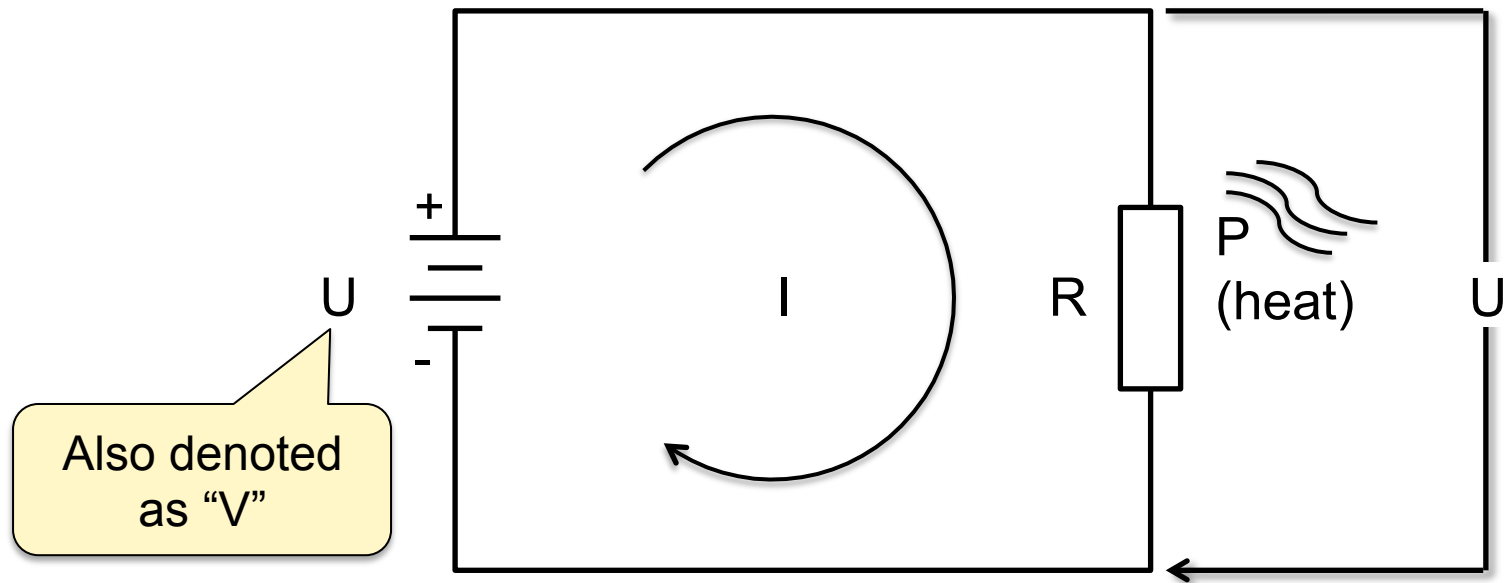
Schedule (preliminary)

Date	Topic (preliminary)
2.5.	Introduction to embedded interaction, microcontrollers, hardware & software tools
9.5.	<i>keine Veranstaltung (CHI)</i>
16.5.	soldering ISP adapter, AVR architecture
23.5.	LED displays, LED multiplexing, transistors, electronics basics
30.5.	AVR architecture, AVR assembler, sensors: light, force, capacity, acceleration, etc.
6.6.	PCB design & fabrication, EAGLE, 3D printing
13.6.	<i>keine Veranstaltung (Pfingsten)</i>
20.6.	I2C: interfacing to other chips (EEPROM, real-time clock, digital sensors)
27.6.	Displays (character LCDs, graphics LCDs), audio (speakers, amplification, op-amps)
4.7.	Actuation: stepper motors, servo motors
11.7.	Communication: fixed-frequency RF, ZigBee, Bluetooth
18.7.	Project
25.7.	Project

ELECTRONICS BASICS

Ohm's Law

- Ohm's Law: $U = I R \Leftrightarrow I = U / R \Leftrightarrow R = U / I \text{ [}\Omega\text{]}$
- Power loss: $P = U I \Leftrightarrow P = I^2 R \Leftrightarrow P = U^2 / R \text{ [W]}$
- Resistor power ratings



Resistors in Series

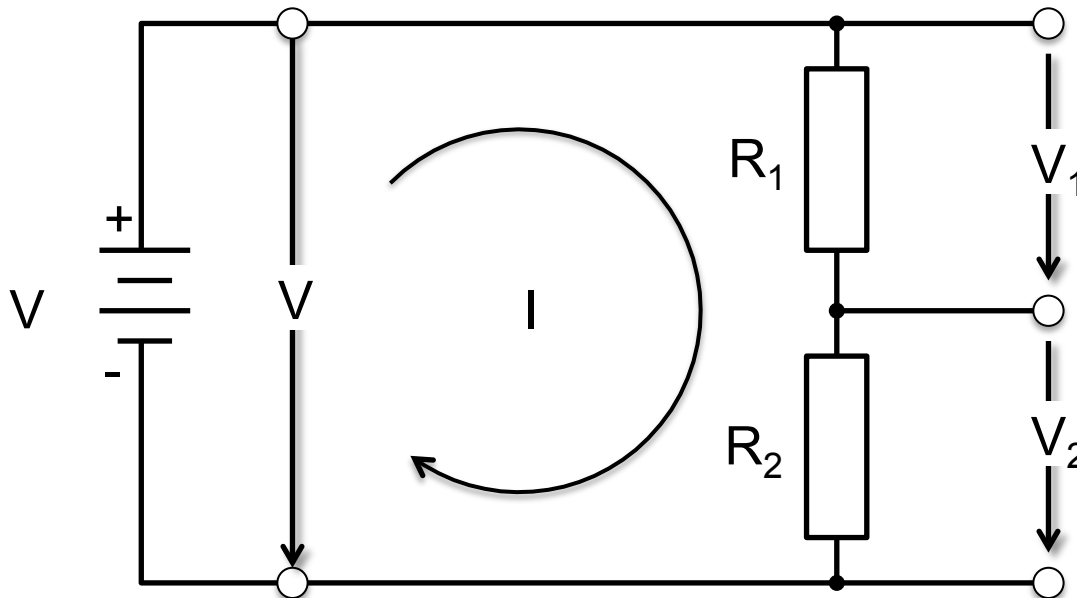
- $V = V_1 + V_2$
- $R = R_1 + R_2$
- Voltage divider

$$V_1 = V R_1 / (R_1 + R_2)$$

$$V_2 = V R_2 / (R_1 + R_2)$$

- Kirchhoff's Voltage Law

$$\sum_{\text{closed loop}} V_i = 0$$



Resistors in Parallel

- $I = I_1 + I_2 \Leftrightarrow U / R = U / R_1 + U / R_2$
 $\Leftrightarrow 1 / R = 1 / R_1 + 1 / R_2$
 $\Leftrightarrow R = R_1 R_2 / (R_1 + R_2)$ (R: resistance)
 $\Leftrightarrow G = G_1 + G_2$ (G: conductance)

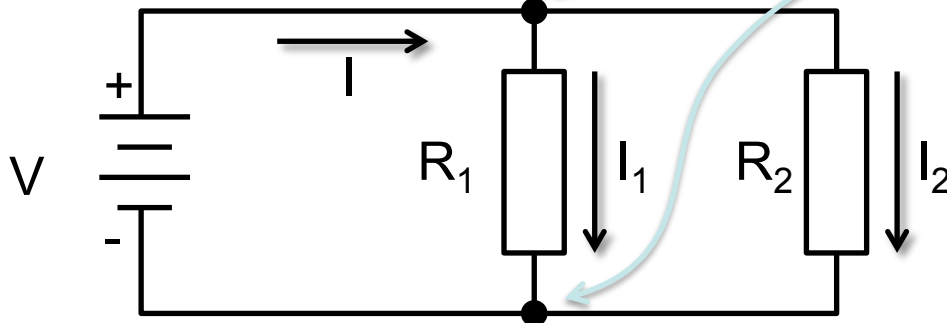
- Current divider

- $I_1 = I R_2 / (R_1 + R_2)$

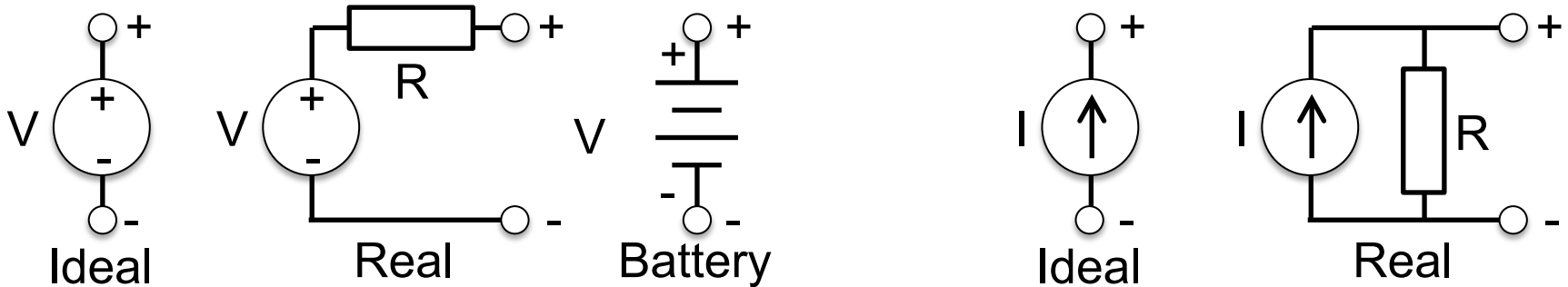
- $I_2 = I R_1 / (R_1 + R_2)$

- Kirchhoff's Current Law

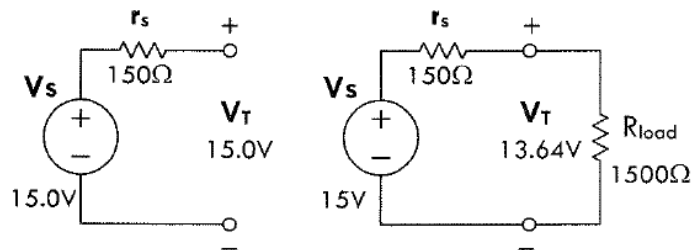
$$\sum_{node} I_i = 0$$



DC Voltage and Current Sources

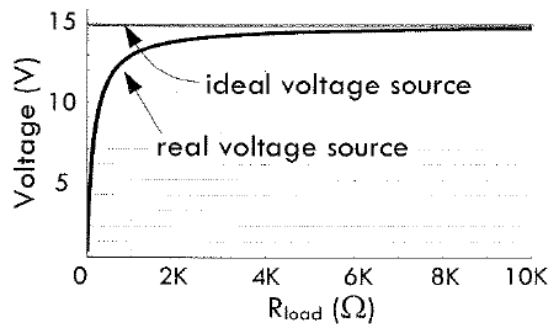


Voltage Source Terminal Voltage

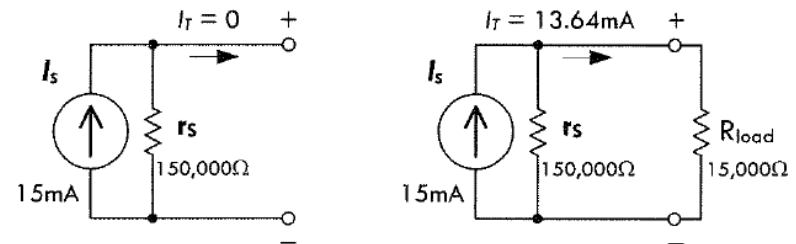


No Load

With Load

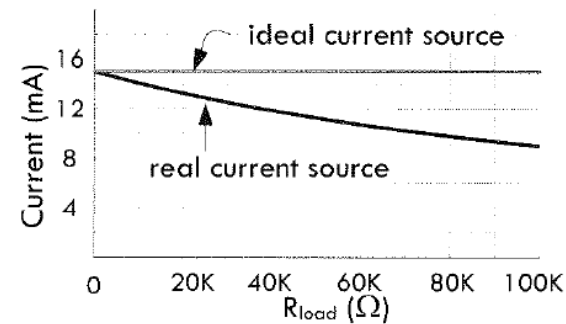


Current Source Terminal Current



No Load

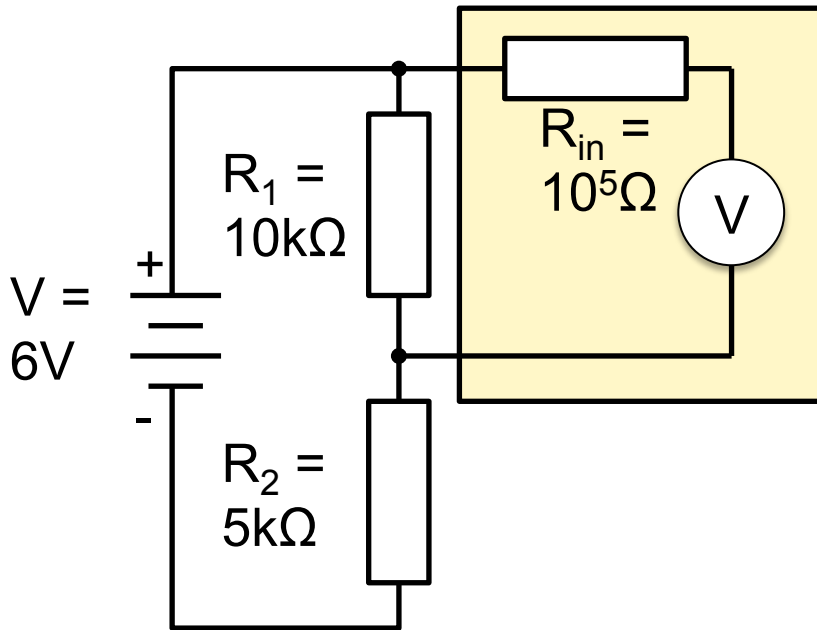
With Load



Source: Paul Scherz: Practical Electronics for Inventors. 2nd edition, McGraw-Hill, 2007.

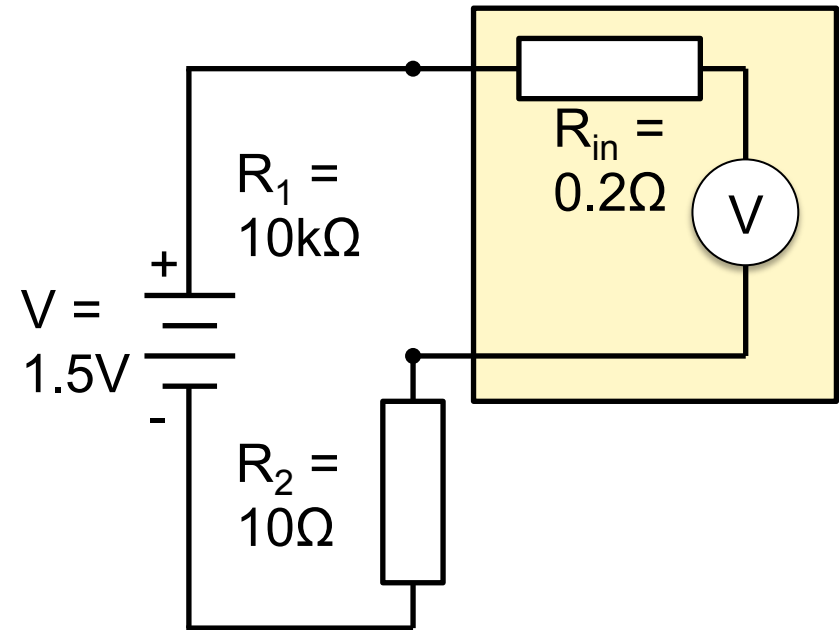
Measuring Voltage and Current

Measuring Voltage:



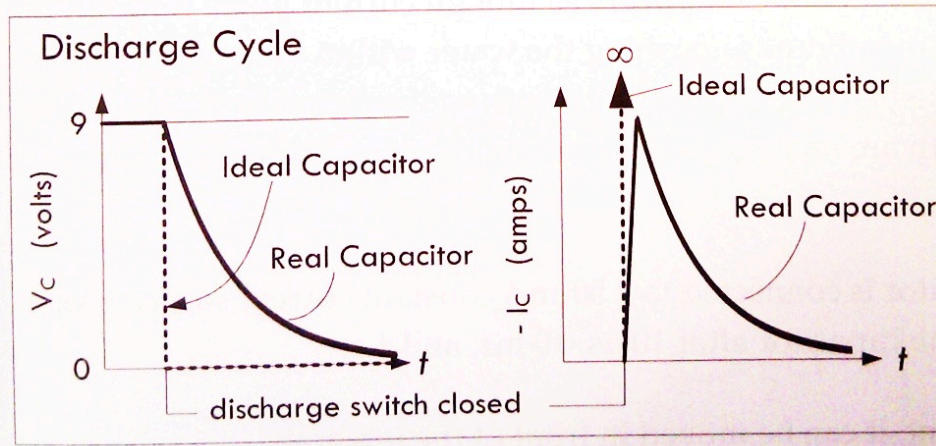
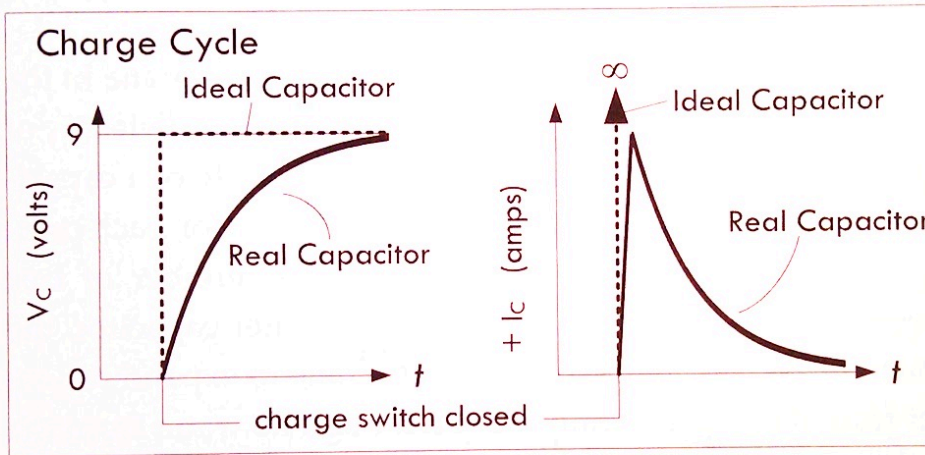
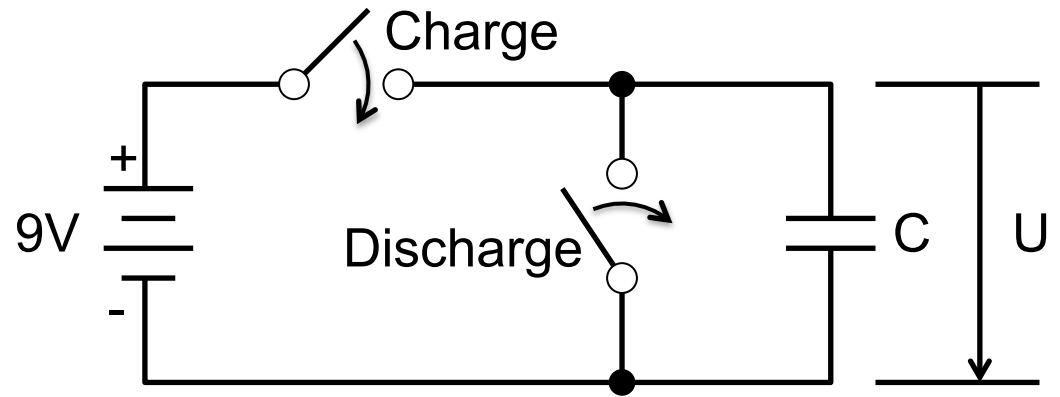
Actual voltage: 4.0V
Measured voltage: 3.9V
3% error

Measuring Current:



Actual current: 150mA
Measured voltage: 147mA
2% error

Charging Capacitors



Source: Paul Scherz: Practical Electronics for Inventors. 2nd edition, McGraw-Hill, 2007.

OPERATION AMPLIFIERS (CONTINUED)

Operational Amplifiers

- Ideal op-amps
 - Rule 1: open-loop voltage gain: $A_O = \infty$
 - Rule 2: Infinite input impedance: $R_{in} = \infty$
 - **Rule 3: Input terminals draw no current**
 - **If negative feedback: Rule 4: $V_+ - V_- = 0$**

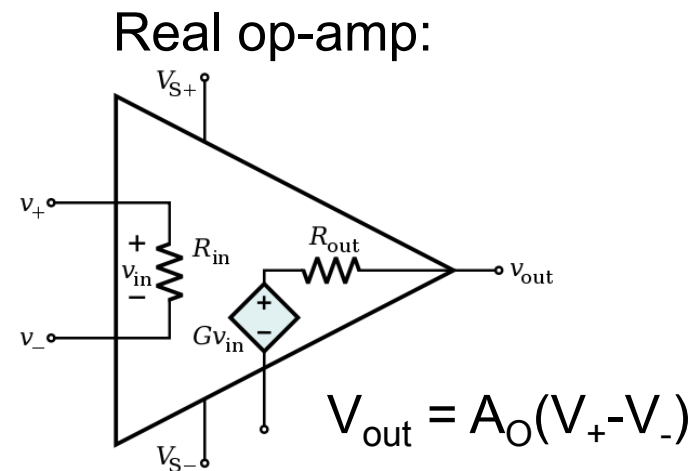
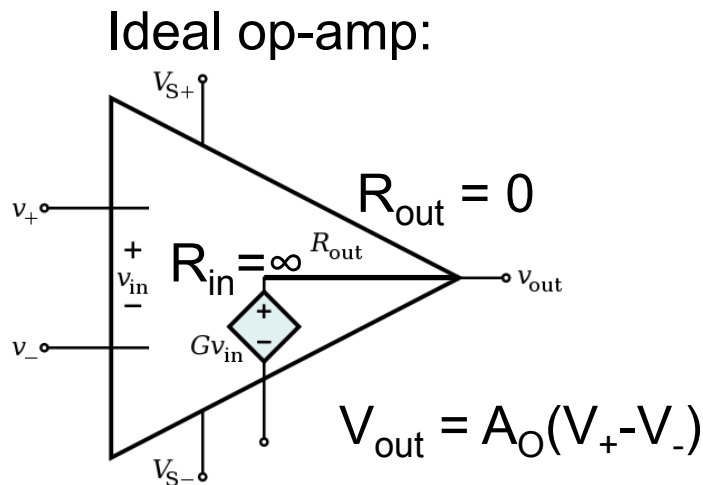


Figure author: Inductiveload, public domain

Operational Amplifiers

- Op-amp circuit diagram

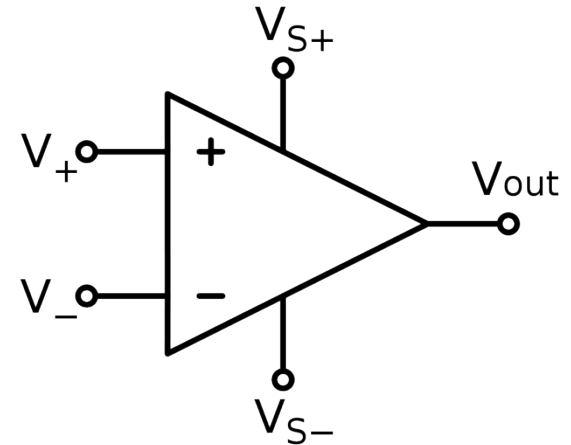
 - V_+ : non-inverting input

 - V_- : inverting input

 - V_{out} : output

 - V_{S+} : positive power supply

 - V_{S-} : negative power supply



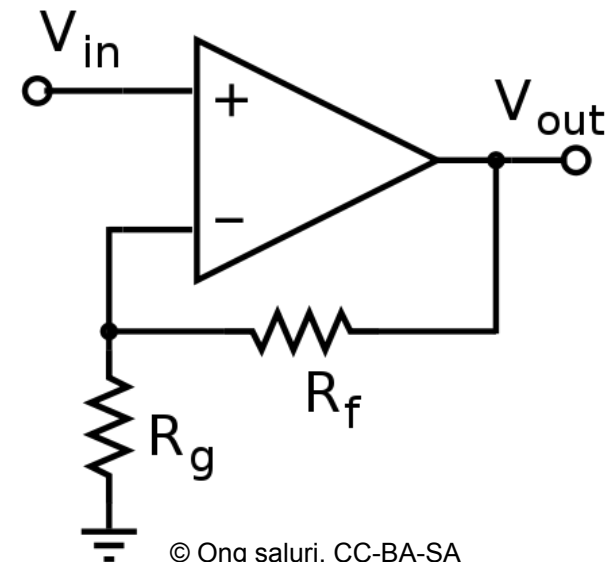
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- Negative feedback

 - Rule 4: $V_+ - V_- = 0$

 - Closed-loop operation

 - Used to control gain (V_{out}/V_{in})

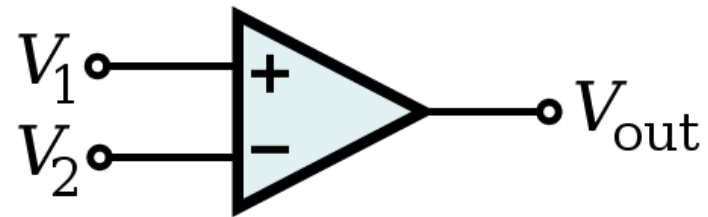


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Op-Amps as Comparators

- Op-amp in open-loop setup (no negative feedback)
 - Ideal op-amp has open-loop voltage gain: $A_O = \infty$
 - Real op-amp voltage limited by supply voltage (V_{S-} , V_{S+})

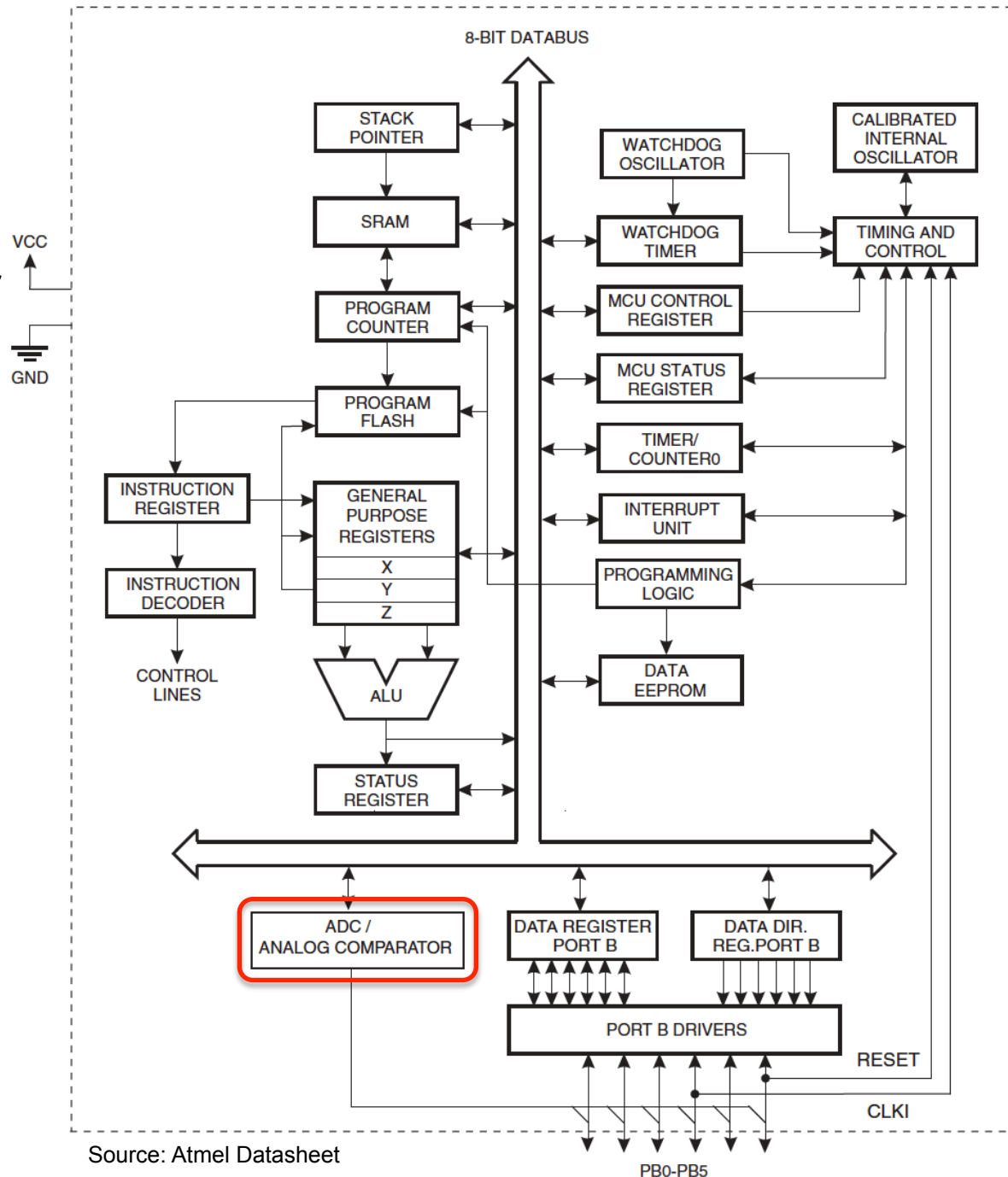
$$V_{out} = \begin{cases} V_{S+} & V_1 > V_2 \\ V_{S-} & V_1 < V_2 \end{cases}$$



- Disadvantages
 - Slow: Op-amps designed for linear operation with negative feedback
 - Compatibility with digital logic not guaranteed
 - → use dedicated comparator chips

AVR ATtiny13 Architecture

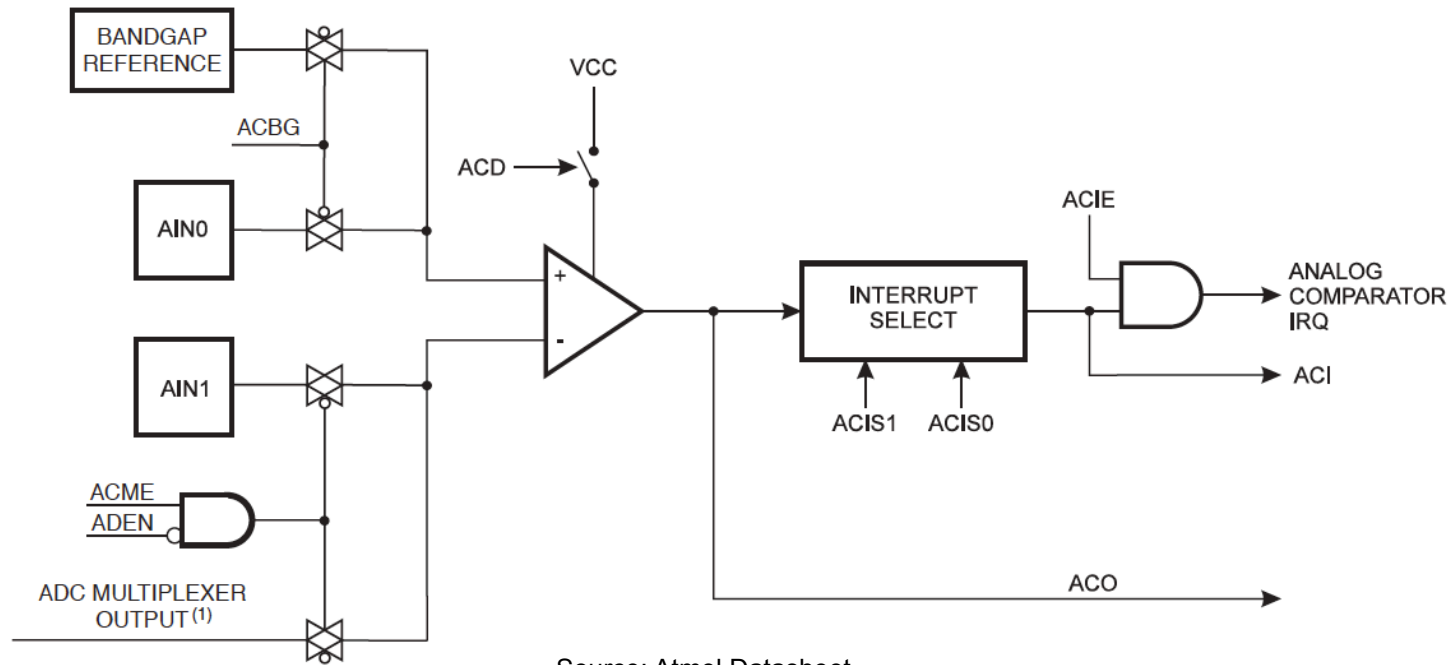
- Analog Comparator



Source: Atmel Datasheet

ATtiny13 Analog Comparator

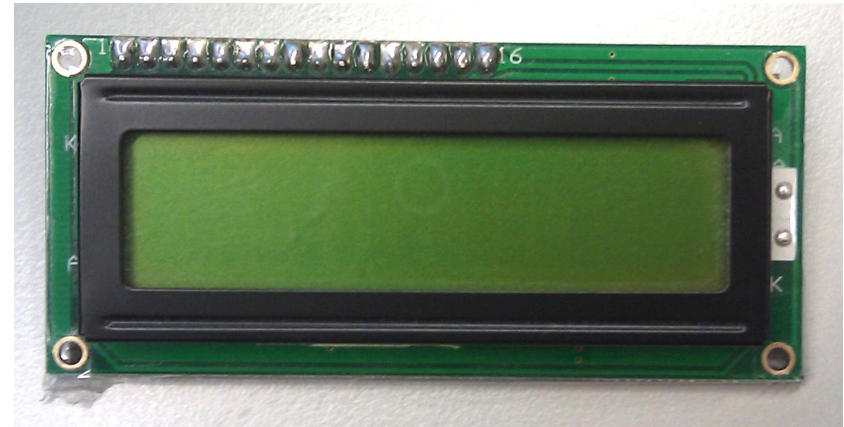
- Compares inputs AIN0 (+) and AIN1(-)
- Sets ACO if AIN0 > AIN1
 - Can trigger interrupt (on ACO rise, fall, or toggle)
- Registers control comparator: ADCSRB, ACSR, DIDR0



Source: Atmel Datasheet

LIQUID CRYSTAL DISPLAYS

LCD Displays



- Typical: 16x2 characters, background illumination
- Standardized pin assignment

Pin No.	Symbol	Function
1	VSS	Ground terminal of module.
2	VDD	Supply terminal of module 5.0V.
3	V0	Power Supply for liquid crystal drive.
4	RS	Register select RS = 0 (Instruction register) RS = 1 (Data register)
5	R/W	Read /Write R/W = 1(Read) R/W = 0 (Write)
6	E	Enable
7	DB0	Bi-directional data bus, data transfer is performed once, thru DB0 to DB7, in the case of interface data. Length is 8-bits; and twice, thru DB4 to DB7 in the case of interface data length is 4-bits. Upper four bits first then lower four bits.
8	DB1	
9	DB2	
10	DB3	
11	DB4	
12	DB5	
13	DB6	
14	DB7	
15	LED - (K)	Please also refer to 6.1 PCB drawing and description.
16	LED + (A)	Please also refer to 6.1 PCB drawing and description.

Table Source: Display
Elektronik GmbH Datasheet

LCD Displays Instruction Set

- Standardized instruction set (HD44780U display driver)
 - Clear display
 - Return home
 - Entry mode set: cursor move direction, display shift
 - Display on/off: switch cursor and/or display on/off
 - Function set (4- or 8-bit interface)
 - Set CGRAM or DDRAM address
(CG = char. generator, DD = display data)
 - Read busy flag
 - Read/write RAM
- Specific initialization procedure to set mode
 - 4- or 8-bit interface

Project Ideas

- Where to use embedded hardware?
- Embedded interaction?
- Displays? Lighting?
- Sensors? Long-term measurements?
- Actuation, motors, movement?
- Communication?
- 3D printing?

Brainwriting

- Repeat 5 times
 - 3 minutes: On paper, fill one row with 3 ideas
 - Pass on paper clockwise
 - Read other ideas, fill next line with 3 more ideas
- Select the 3 best ideas
 - 10 minutes
 - Present selected ideas
