

# Power management and I/O peripherals in embedded systems

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# Batteries

- Non-rechargeable (primary, single-use, disposable) batteries
  - Recharging is not allowed or may explode
  - Inverse current not tolerated
    - Diode can be used to protect from inverse current
  - Capacity: 20mAh...300mAh -> coin cell  
300mAh...3000mAh -> AA/AAA

- Rechargeable batteries

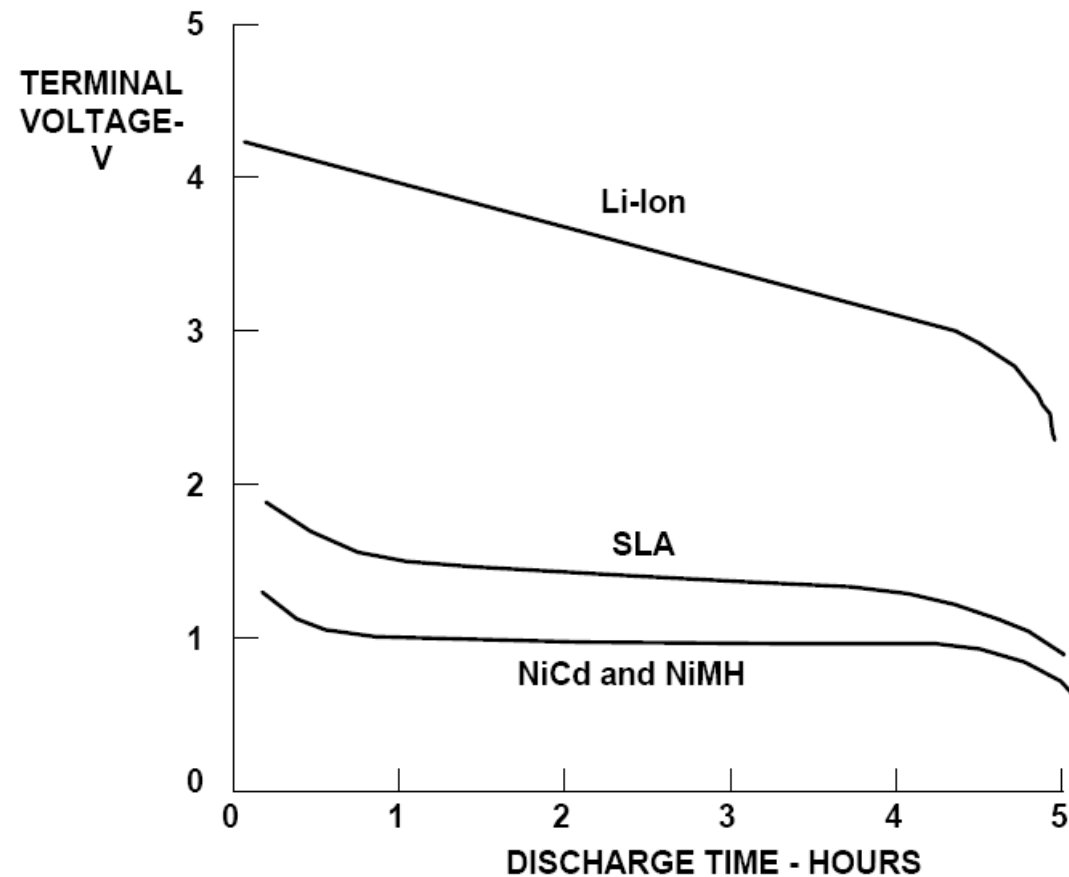
	Sealed Lead-Acid	Nickel Cadmium*	Nickel Metal Hydride*	Lithium Ion*	Lithium Metal*
Average Cell Voltage (V)	2	1.20	1.25	3.6	3.0
Energy Density (Wh/kg)	35	45	55	100	140
Energy Density (Wh/l)	85	150	180	225	300
Cost (\$/Wh)	0.25 - 0.50	0.75 - 1.5	1.5 - 3.0	2.5 - 3.5	1.4 - 3.0
Memory Effect?	No	Yes	No	No	No
Self-Discharge (%/month)	5 - 10	25	20 - 25	8	1 - 2
Discharge Rate	<5C	>10C	<3C	<2C	<2C
Charge/Discharge Cycles	500	1000	800	1000	1000
Temperature Range ( °C)	0 to +50	-10 to +50	-10 to +50	-10 to +50	-30 to +55
Environmental Concerns	Yes	Yes	No	No	No

\* Based on AA-Size Cell

- Capacity:  $C$  [Ah, mAh]= battery life between charges
- Battery current:  $C\text{-rate} = C/1\text{h}$ 
  - Example: 1000mAh battery has a C-rate of 1000mA
    - $1C \rightarrow 1000\text{mA}$
    - $0.1C \rightarrow 100\text{mA}$
- Memory effect: only for NiCd, but rare
  - Several discharging to the same level after full recharge  $\rightarrow$  cell potential drops below normal, capacity is not affected
    - Solution: full discharging and recharging twice

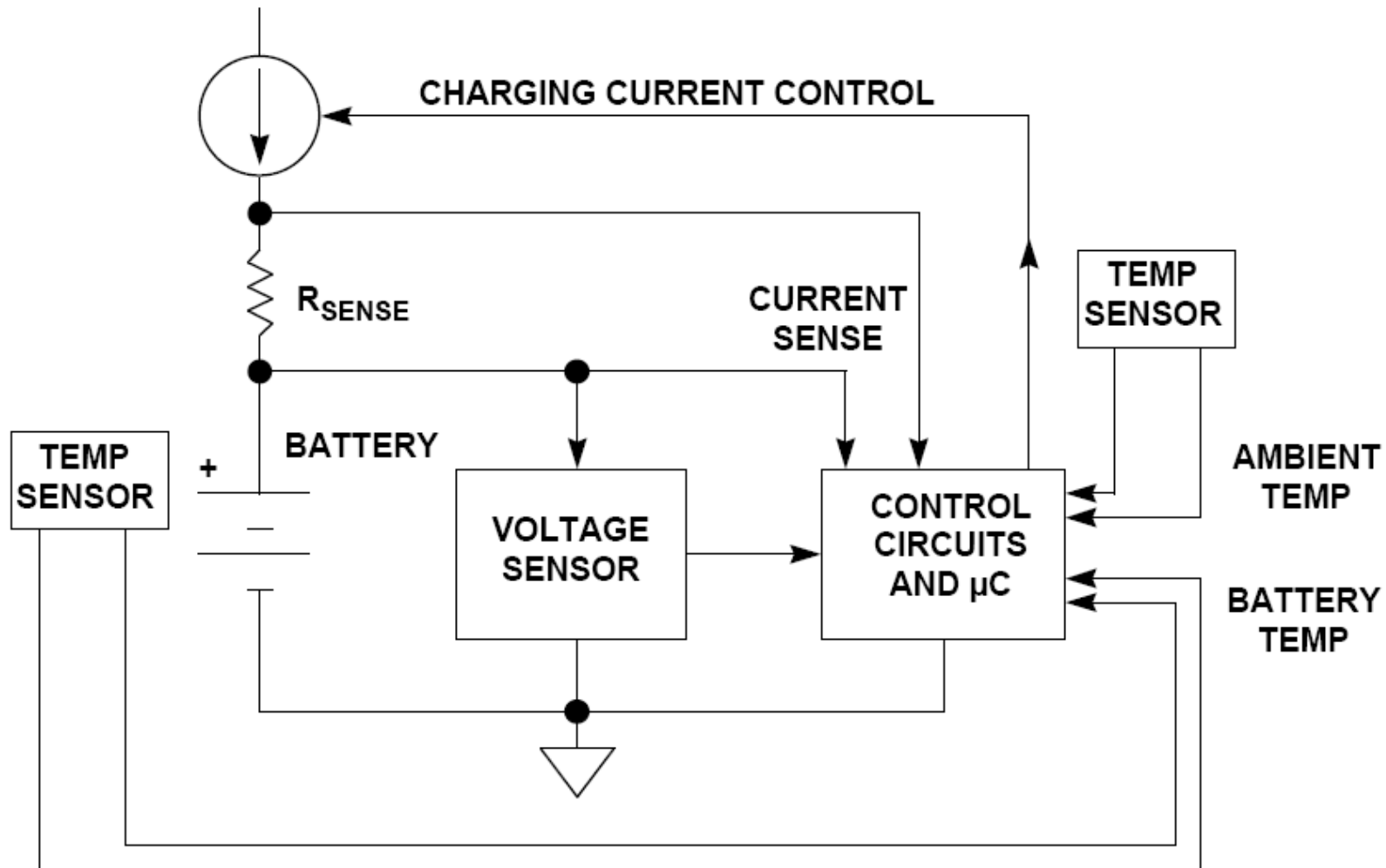
# Battery charging, chargers

- Battery discharge profile at 0.2C-rate

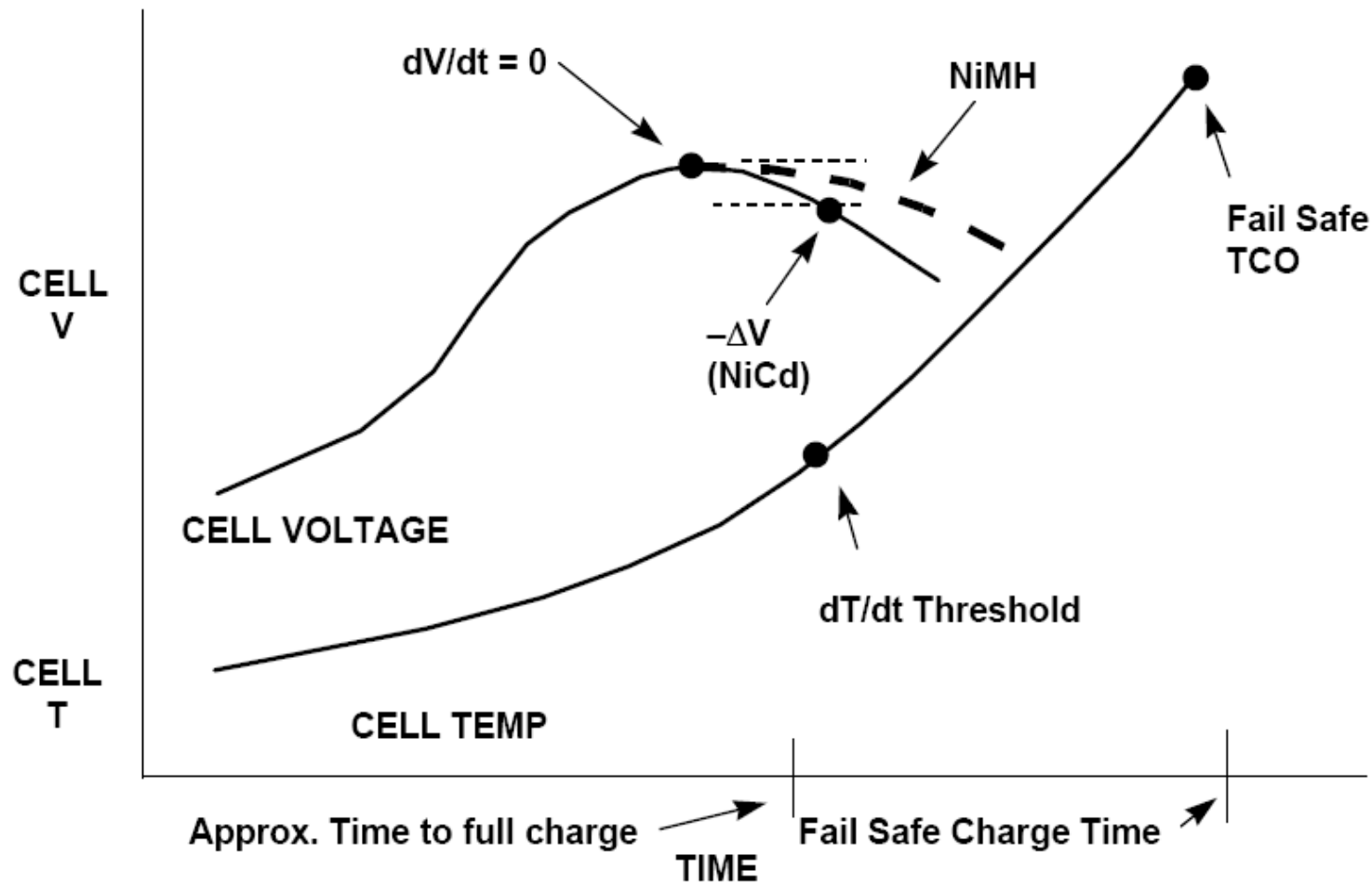


- Charging duration
  - Slow  $>12\text{h}$   $\rightarrow$  simple charger (current source)
  - Fast  $<3\text{h}$   $\rightarrow$  complex charger (monitoring temperature, etc.)
  - Trickle (continuous) indefinitely long (NiMH 0.03C)

- Generalized battery charger unit

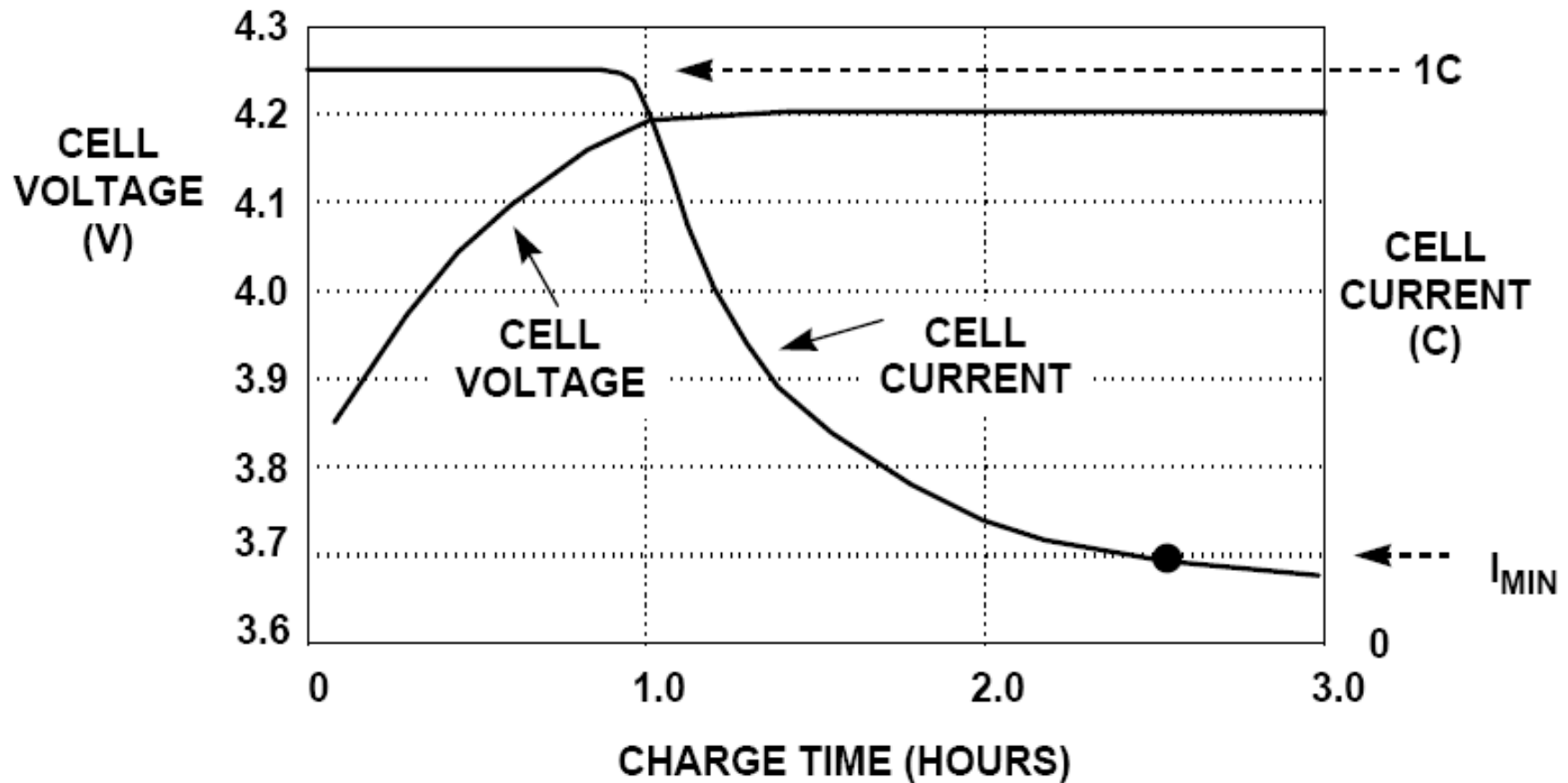


- NiCd/NiMH battery temperature and voltage charging characteristics

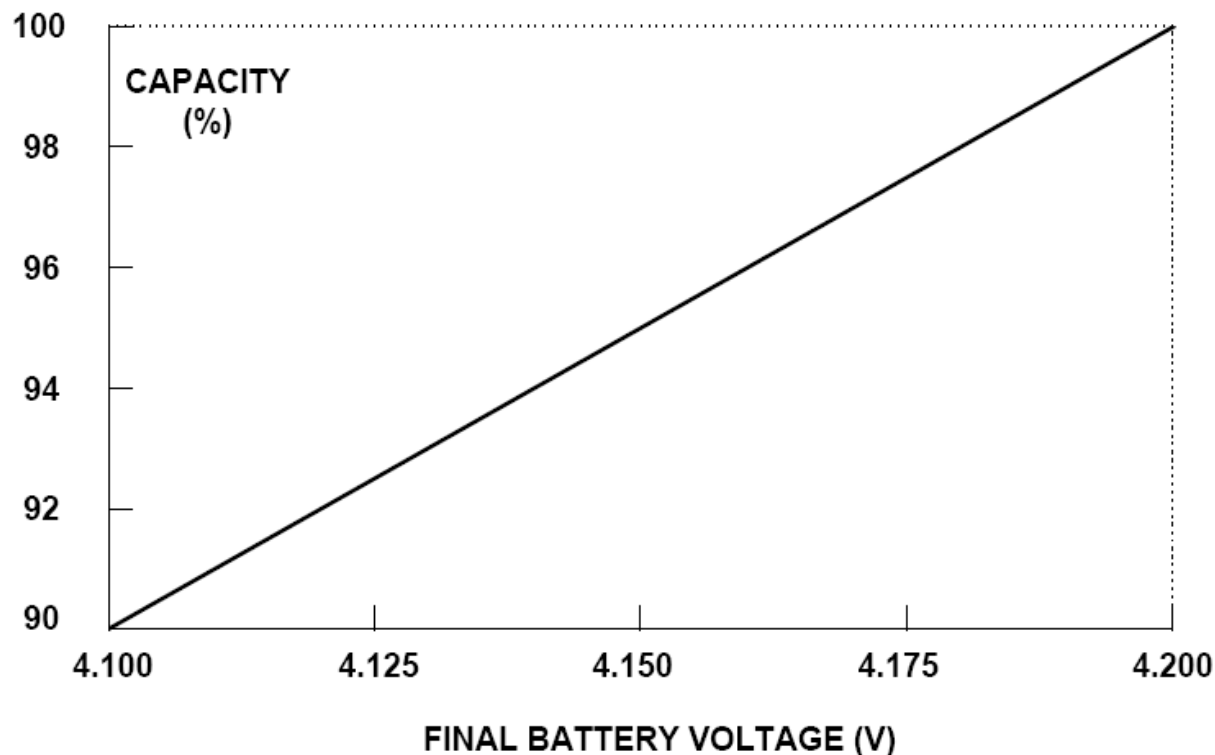




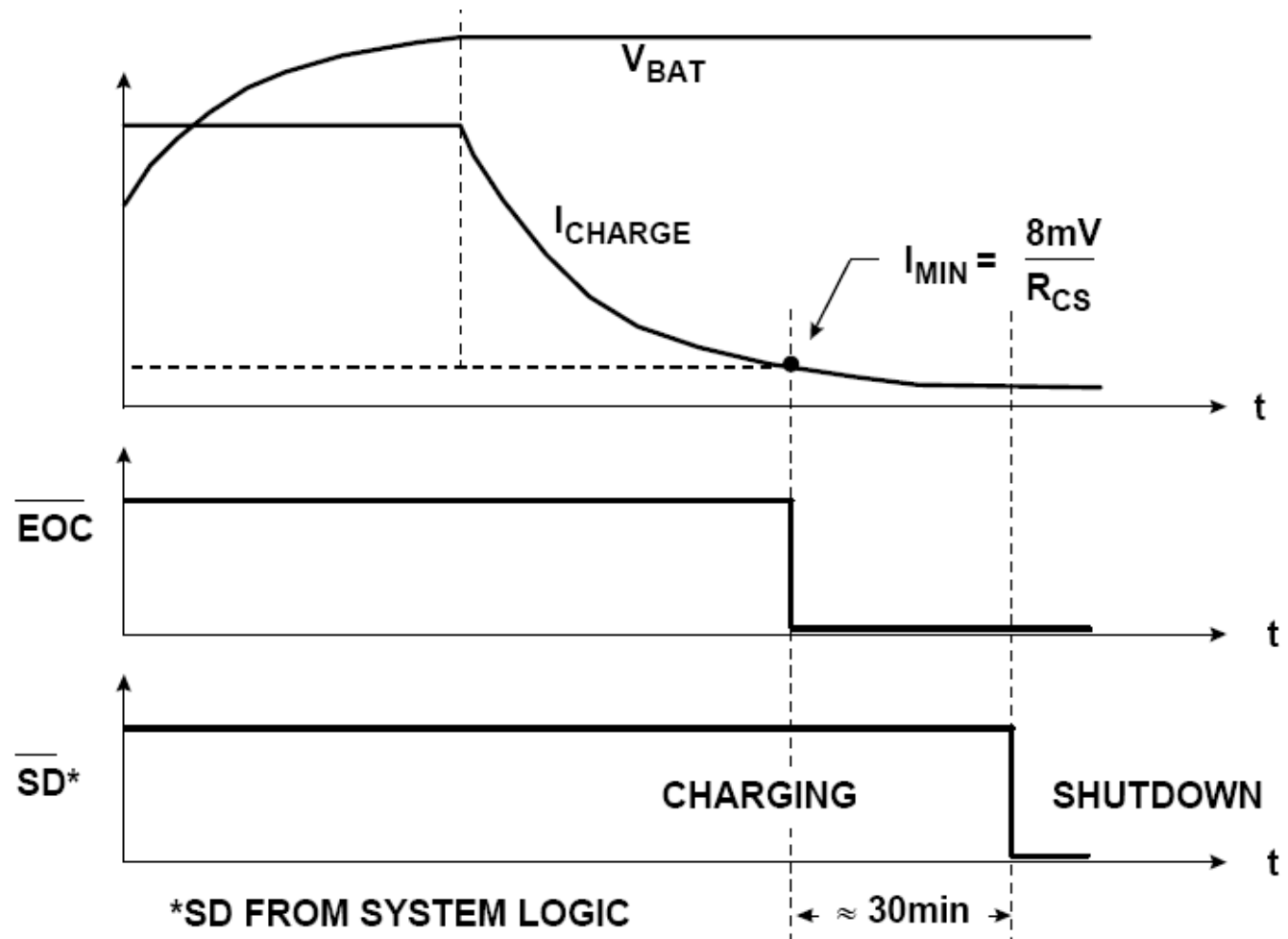
- Li-Ion fast charging characteristics



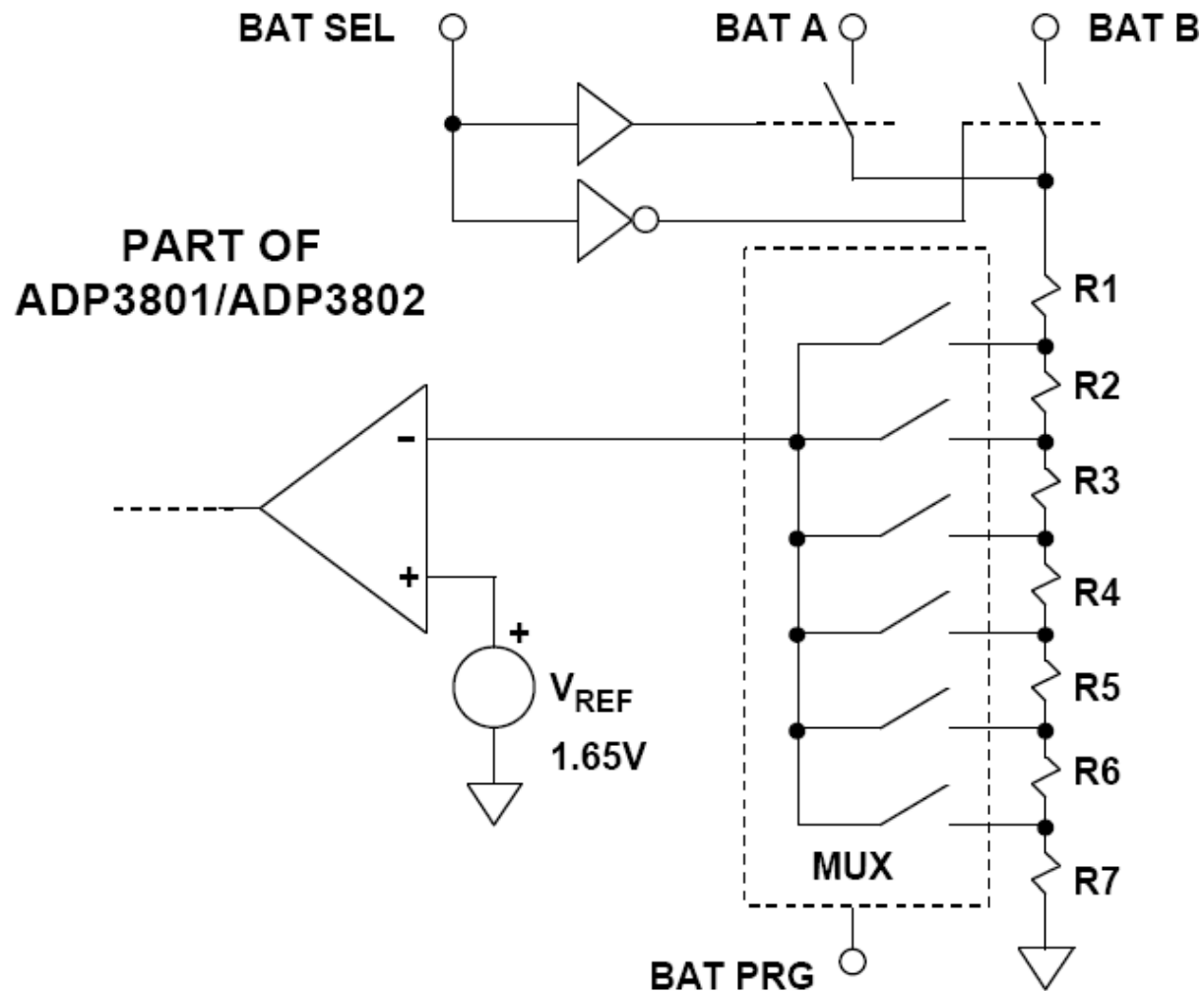
- Effect of undercharge of Li-Ion battery capacity
  - Accurate control of final charging voltage
  - Undercharging by 100mV-> 10% capacity lost



- End of charge detection in uC controlled charger
  - Li-Ion!

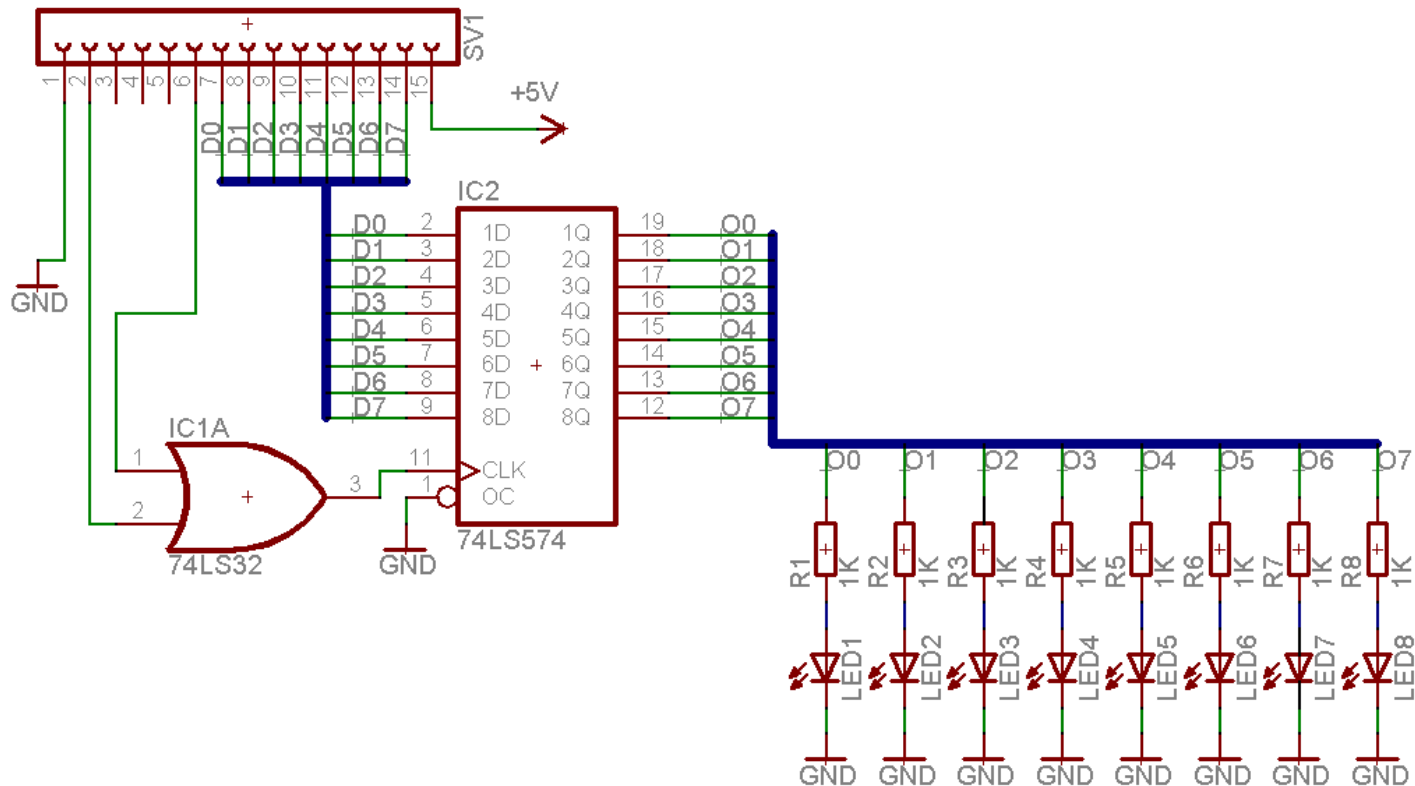


- Using MUX to select battery voltage

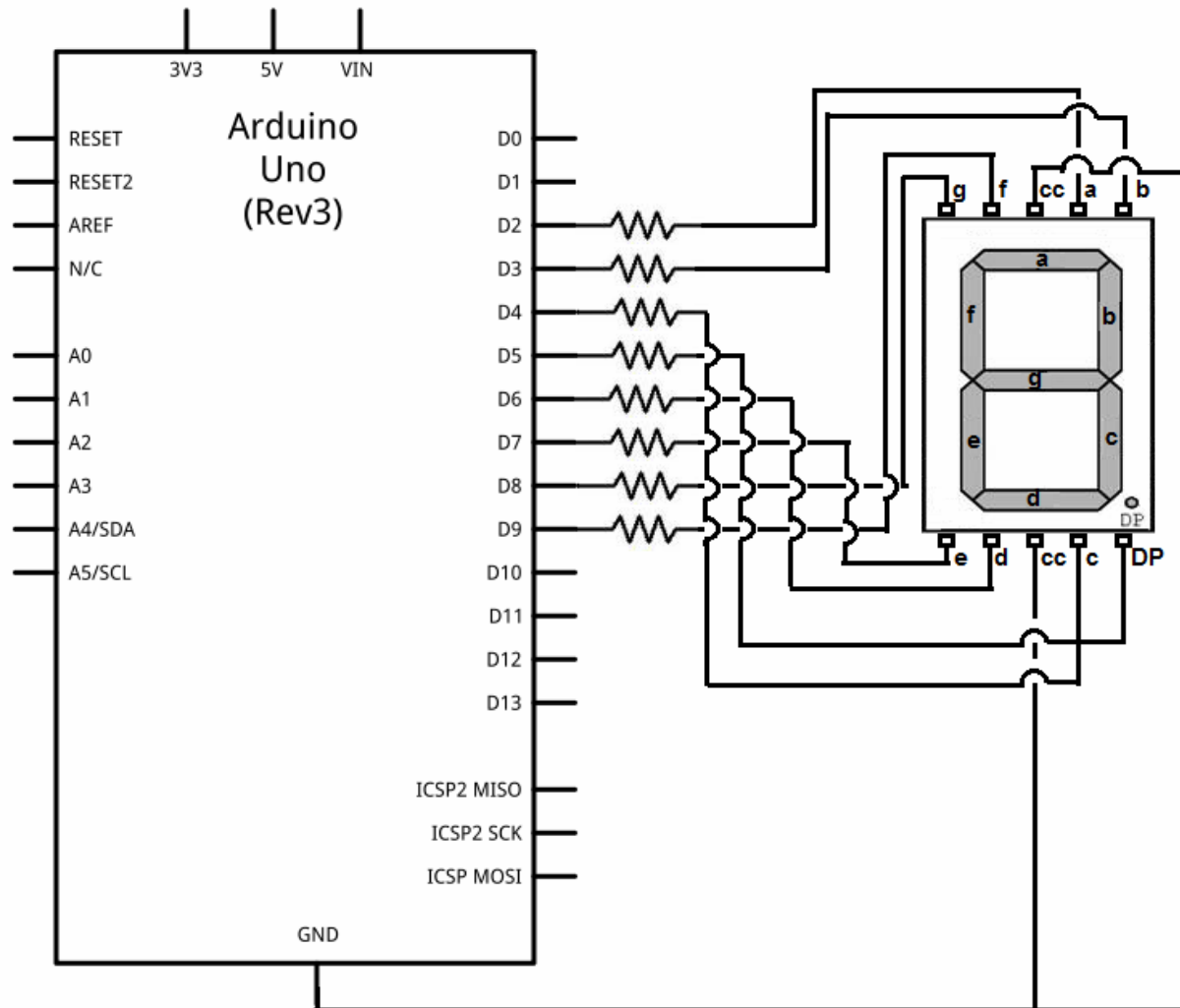


# Displays

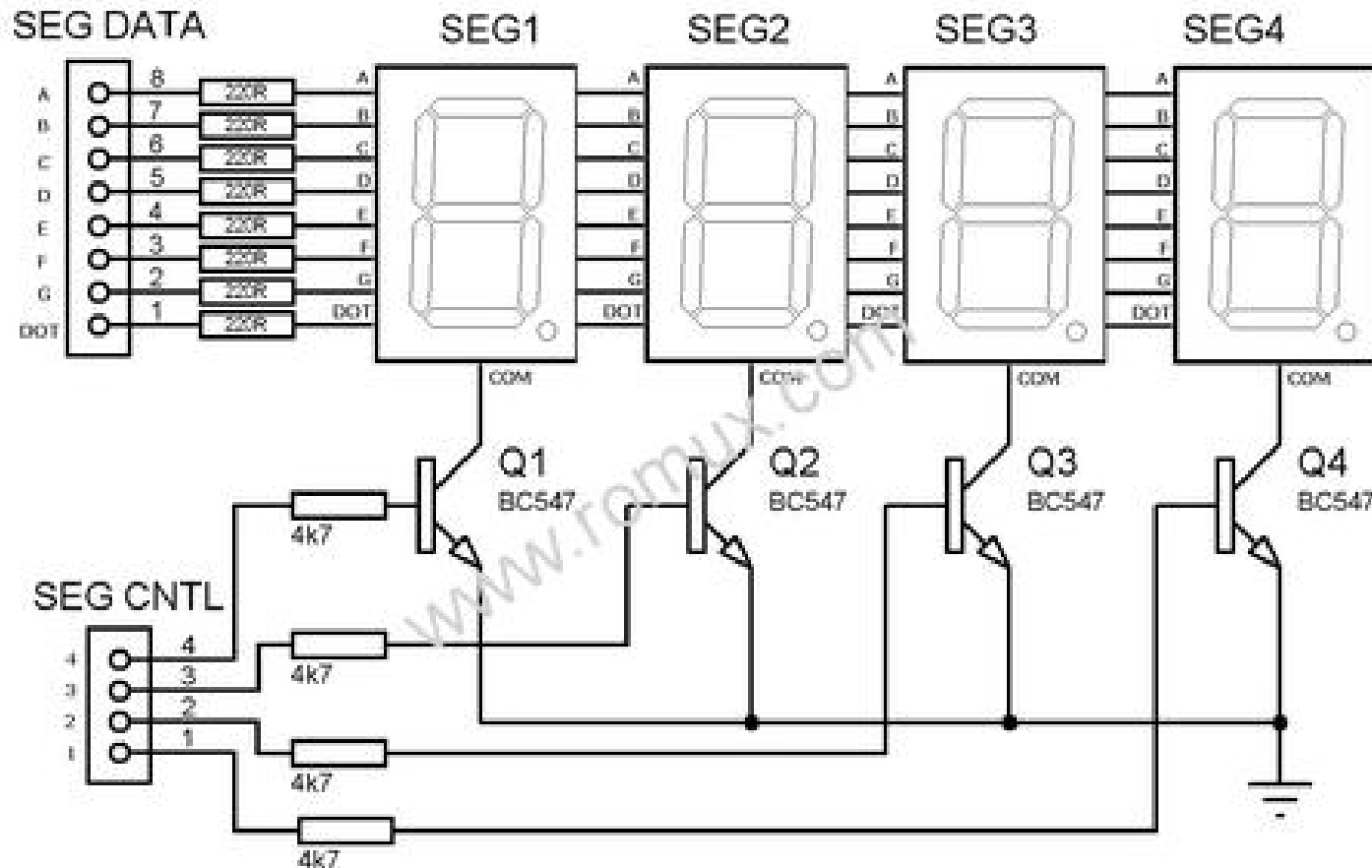
- LED: pull-up resistors 220...470 Ohm



- 7-segment display



- Multiplexed display: displays at 50Hz



- LCD
  - Hitachi 44780 LCD controller
    - Pinout:
      - GND
      - Vcc (+3.3V...+5V)
      - Contrast adjustment (V0)
      - Register select RS=0->command; RS=1 -> data
      - Read/write
      - CLK (Enable)
      - D0...D7 data
      - Backlight +/- (anode/cathode)
    - Typical instructions:
      - Clear display



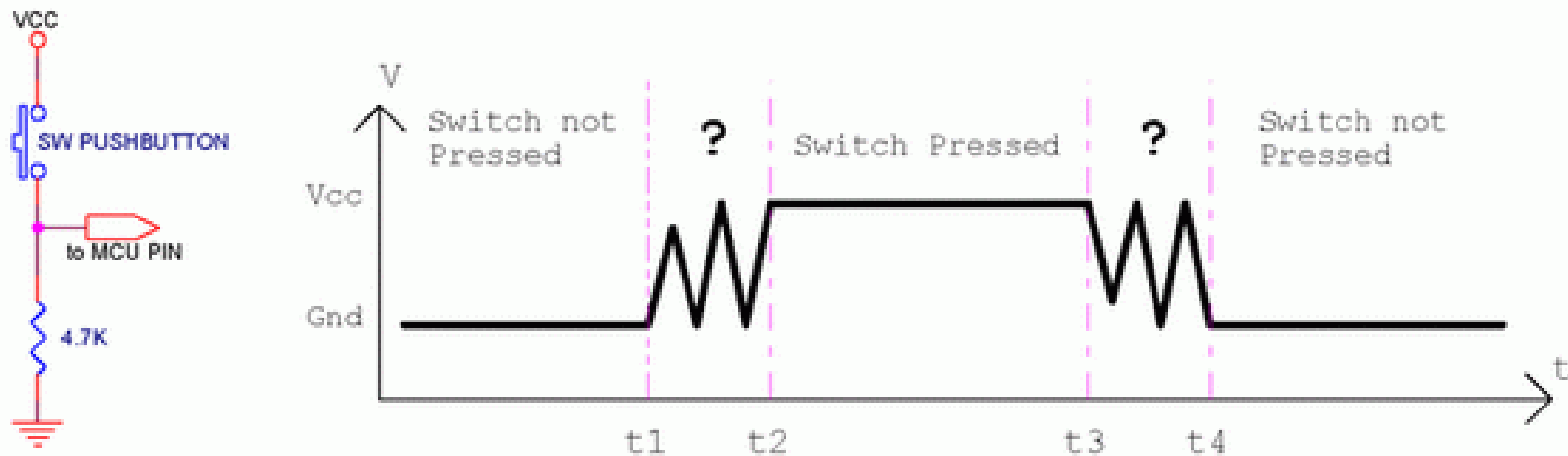
For 5 × 10 dot character patterns

Character Codes (DDRAM data)								CGRAM Address				Character Patterns (CGRAM data)													
7	6	5	4	3	2	1	0	5	4	3	2	1	0	7	6	5	4	3	2	1	0				
High				Low				High		Low		High				Low									
0 0 0 0 * 0 0 *								0 0				0	0	0	0	* * *	0	0	0	0	0				
												0	0	0	0	* * *	0	0	0	0	0				
												0	0	0	0	* * *	0	0	0	0	0				
												0	0	0	0	* * *	0	0	0	0	0				
												0	0	0	0	* * *	0	0	0	0	0				
												0	0	0	0	* * *	0	0	0	0	0				
												0	0	0	0	* * *	0	0	0	0	0				
												0	0	0	0	* * *	0	0	0	0	0				
												0	0	0	0	* * *	0	0	0	0	0				
												0	0	0	0	* * *	0	0	0	0	0				
0 0 0 0 * 1 1 *								1 1				0	0	0	0	* * *	0	0	0	0	0				
												0	0	0	0	* * *	0	0	0	0	0				
												0	0	0	0	* * *	0	0	0	0	0				
												0	0	0	0	* * *	0	0	0	0	0				
												0	0	0	0	* * *	0	0	0	0	0				
												0	0	0	0	* * *	0	0	0	0	0				
												0	0	0	0	* * *	0	0	0	0	0				
												0	0	0	0	* * *	0	0	0	0	0				
												0	0	0	0	* * *	0	0	0	0	0				
												0	0	0	0	* * *	0	0	0	0	0				

- Cursor home
- Character write/read
- Display on/off
- Cursor blink
- User defined character

# Input devices

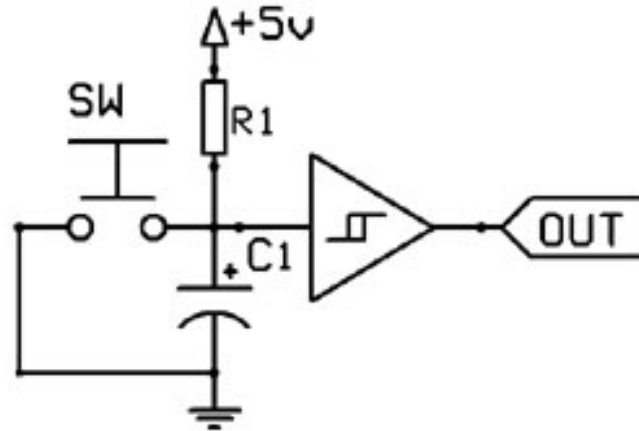
- Push button



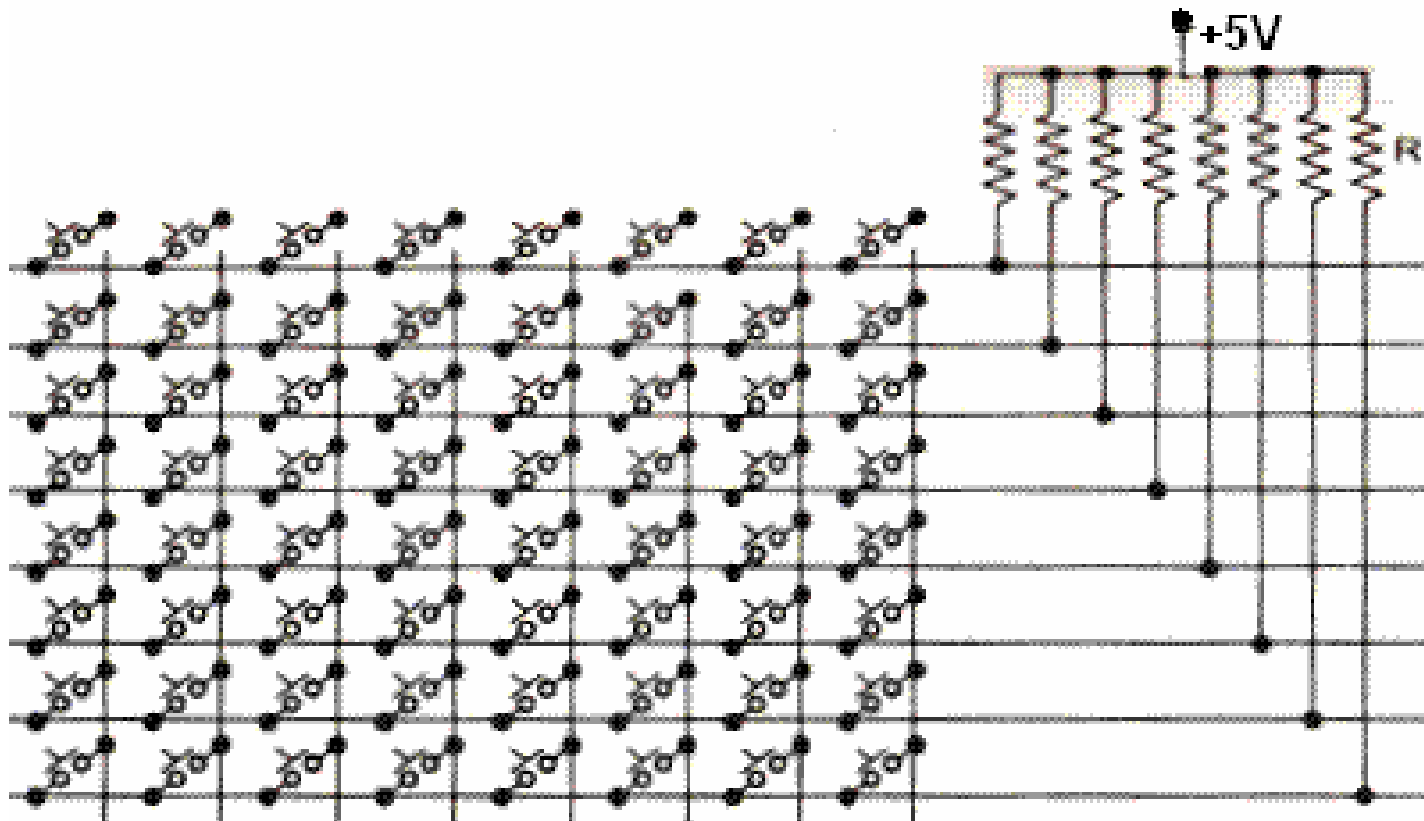
Pull-DOWN connection

- Problem: transient between switch position (prell)
  - Solution: schmitt trigger (no-prell)

- Push button with Schmitt-trigger



- Keyboard matrix
  - Pull-up resistors are used
  - Can be integrated into uC



# References

- Analog devices: Practical design techniques for power and thermal management