Systems Engineering

Power Supplies

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iTIC http://itic.cat

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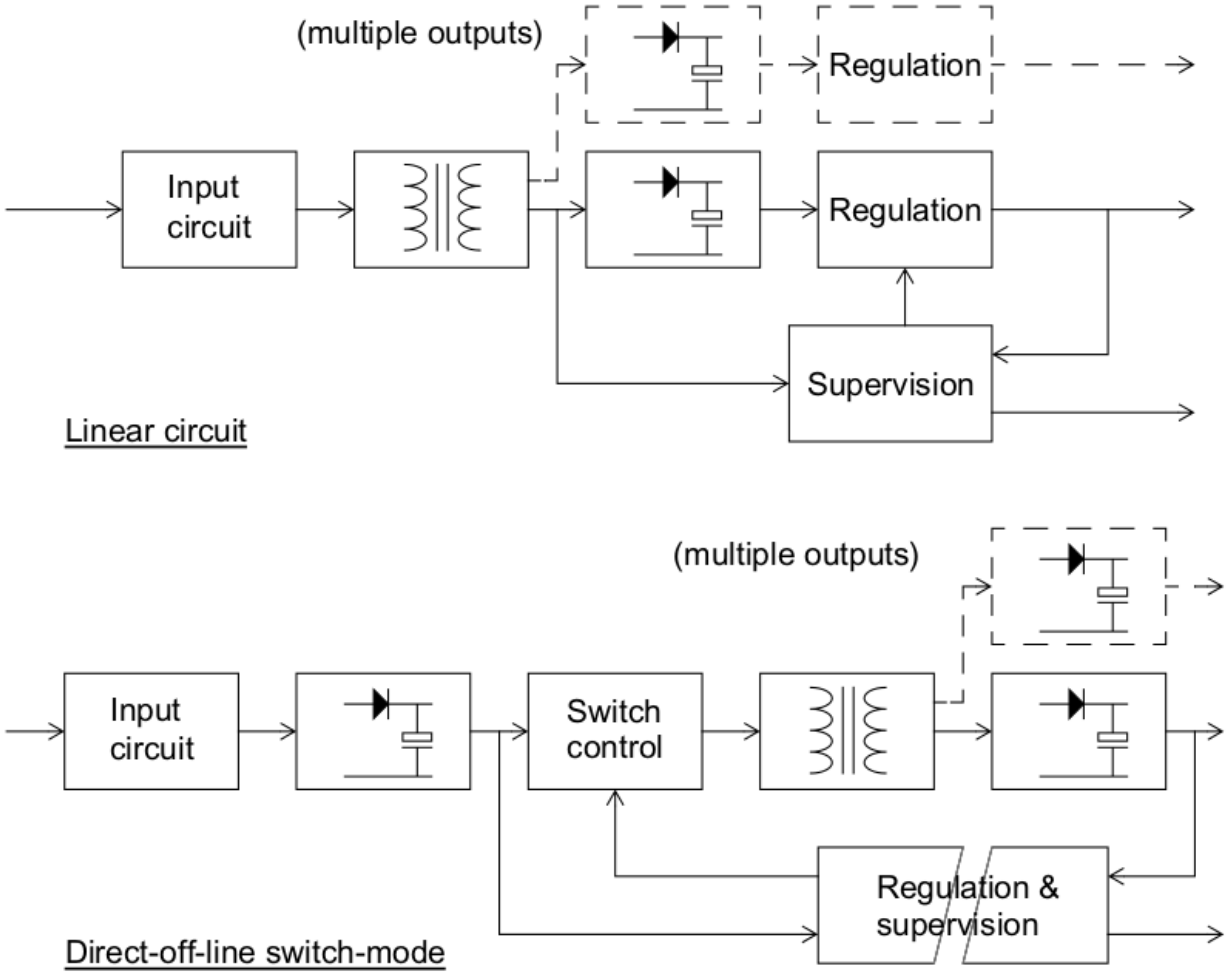
Block Diagrams



Source: The Circuit Designer's Companion

Linear supply

- Input circuit
- Transformer
- Rectifier
- Reservoir
- Regulation
- Supervision

Switch-mode supply

- Rectifier + reservoir
- Switcher
- Eliminate 50 Hz mains transformer
- Substitute by a 100 kHz transformer: less weight and volume
- Rectifier + small-value reservoir due to high frequency
- Regulation
- Supervision

Specifications

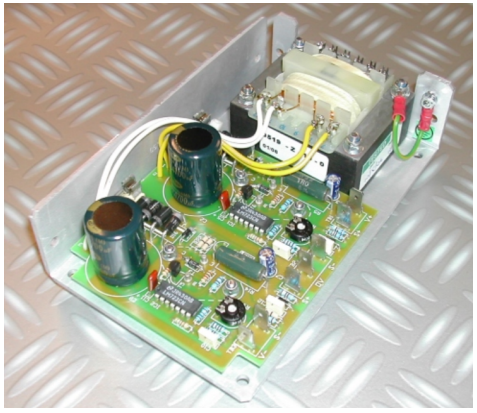
- Input paremeters
  - Minimum and maximum input voltage
  - Maximum input current (surge and continuous)
  - Frequency range
- Efficiency over range of load and line conditions
- Output parameters
  - Output voltage(s)
  - Load current(s)
  - Output ripple and noise
  - Load and line regulation
  - Transient response
- Overload
- Turn-on, turn-off
- Mechanical parameters
- Safety approvals

Commercial power supplies

Linear Power supplies

- Fixed / adjustable
- Output voltage: 5 V..5 kV
- Number of outputs
- Output current: 3 mA..50 A
- Power rating: 0.5 W..500 W

Linear power supplies



R3 Part No.	Description	L (mm)	W (mm)	H (mm)	Wt (Kg)	EMS Ref	Cover Kit
00-3500	5V 3A	124	102	53	1.0	D500	00-3880
00-3501	5V 6A	143	124	75	1.8	D501	00-3881
00-3502	5V 12A	229	124	81	3.4	D502	00-3882
00-3503	12-15V 1.7A	124	102	53	1.0	D503	00-3880
00-3504	12-15V 3.4A	143	124	75	1.8	D504	00-3881
00-3505	12-15V 6.8A	229	124	81	3.4	D505	00-3882
00-3506	24-28V 1.2A	124	102	53	1.0	D506	00-3880
00-3507	24-28V 2.4A	143	124	75	1.8	D507	00-3881
00-3508	24-28V 3.6A	178	124	81	3.2	D508	00-3883
00-3509	24-28V 4.8A	229	124	81	3.4	D509	00-3882
00-3510	24-28V 7.2A	356	124	86	4.2	D510	00-3885
00-3511	24-28V 10A	356	124	86	4.2	D511	00-3885
00-3512	±12-15V 1.7A	178	124	75	1.0	D512	00-3883
00-3513	±12-15V 3.4A	238	124	81	1.8	D513	00-3884
00-3514	5V 2A ± 9-15V 0.4A	165	102	53	1.0	D514	00-3886
00-3515	5V 3A ± 12-15V 1A	260	102	75	1.8	D515	00-3887
00-3516	5V 6A ± 12-15V 1.7A	279	124	81	3.2	D516	00-3888
00-3517	48V 1.0A	143	124	75	1.0	D517	00-3881
00-3518	120-200V 0.15A	124	102	53	2.3	D518	00-3880
00-3519	± 12-15V 1.0A	165	102	53	3.6	D519	00-3886

Linear power supplies

1 Watt Encapsulated AC-DC Linear Power Supply

PRODUCT DESCRIPTION

A comprehensive range of PCB mounting encapsulated power supplies available in either 120Vac or 230Vac input versions, and in single or dual output formats. They are vacuum encapsulated in flame retardant epoxy resin to UL94V0. All units incorporate overcurrent and reverse protection, and will automatically recover upon removal of the fault condition. The input and output pins are on 2.54mm, (0.1") centres for easy PCB mounting. All units also include a 'one shot' thermal fuse to protect against excessive over temperature conditions. The units are fully approved to EN60950 and are compliant to Low Voltage Directive.

Part Number	AC Input Range	Output Voltage	Output Current	Line Reg (Full Input Swing)	Load Reg (0-100%)
EPS 5/200C	207-253V	5V +/-5%	0-200mA	20mV	60mV
EPS 12/100C	207-253V	12V +/-5%	0-100mA	20mV	60mV
EPSD 12/50C	207-253V	+/-12V +/-5%	0-50mA	20mV	60mV
EPSD 15/40C	207-253V	+/-15V +/-5%	0-40mA	20mV	60mV
EPSL 5/200C	108-132V	5V +/-5%	0-200mA	20mV	60mV
EPSL 12/100C	108-132V	12V +/-5%	0-100mA	20mV	60mV
EPSDL 12/50C	108-132V	+/-12V +/-5%	0-50mA	20mV	60mV
EPSDL 15/40C	108-132V	+/-15V +/-5%	0-40mA	20mV	60mV

PRODUCT SPECIFICATION & DIMENSIONS

Input frequency Range	47-63Hz
Isolation test Voltage	3KV AC RMS Input to Output
Output Ripple	10mV Peak to peak (maximum)
Output Protection	All Outputs are short circuit protected
Operating Temperature Range	0ºC to +40ºC
Weight	0.155Kg

Linear power supplies

- 100mA @ +5V d.c. Regulated Output
- Very Compact Design
- Simple Screw-Terminal Connection
- Encapsulated Mains Transformer
- Use with Lascar Panel Meters

Standard Unit			Stock Number PSU 30205	
Specification	Min.	Typ.	Max.	Unit
Load regulation			1	%
Line regulation			1	%
Ripple			0.5	mV
Operating temperature	0		70	°C
Output Voltage		5		V d.c.
Output Current		100		mA
Input (50-60Hz)	220	240	250	V a.c.

Switch-mode power supplies (enclosed)

Switch-mode power supplies (enclosed)

Specification

Input

Input Voltage	• 85-264 VAC (127-370 VDC), see derating curve
Input Frequency	• 47-63 Hz
Input Current	• VCS50: 1.1 A, VCS70: 1.4 A, VCS100: 2.0 A typical at 90 VAC
Inrush Current	• 60 A max at 230 VAC, cold start at 25 °C
Power Factor	• EN61000-3-2 Class A
Earth Leakage Current	• 1.0 mA maximum
Input Protection	• 50 & 70 W: T3.15 A/250 V 100 W: T4.0A/250 V, fuse fitted in live line
No Load Input Power	• <0.5 W

Output

Output Voltage	• See model table
Output Adjust	• ±10.0% (5 V & 12 V versions are -5% to +10%)
Initial Set Tolerance	• ±1.0%
Minimum Load	• None required
Start Up Delay	• 1 s maximum
Hold Up Time	• 10 ms min at 115 VAC and full load
Line Regulation	• ±0.5%, 90 VAC to 264 VAC input
Load Regulation	• 5 V & 12 V versions: ±1%, Others: ±0.5% 0% to 100% load
Transient Response	• Less than 4% deviation with a 50% to 75% load change at 1 A/µs. Output returns to within 1% in less than 500 µs
Ripple & Noise	• 1% maximum pk-pk, 20 MHz bandwidth
Overvoltage Protection	• 120-140% of nominal output, auto recovery
Overload Protection	• 110-150% of nominal, trip and restart
Short Circuit Protection	• Continuous trip and restart
Temperature Coefficient	• ±0.03%/°C after 20 min warm up

General

Efficiency	• See tables
Isolation	• 3000 VAC Input to Output 1500 VAC Input to Ground 500 VAC Output to Ground
Switching Frequency	• 65 kHz typical
MTBF	• >500 kHrs to MIL-STD-217F at 25 °C, GB

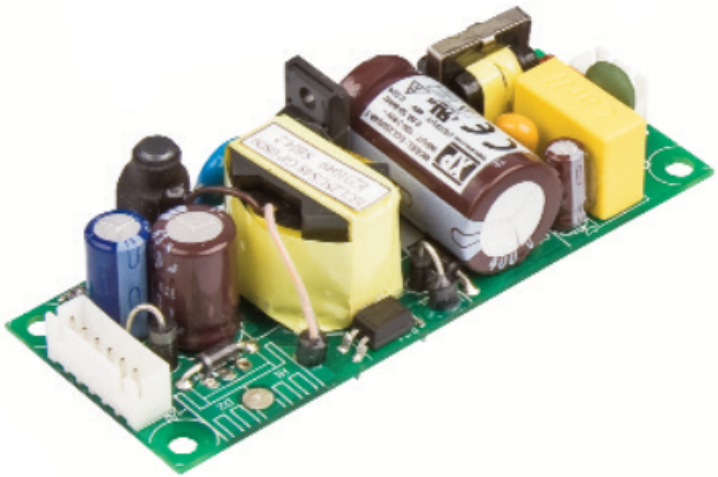
Environmental

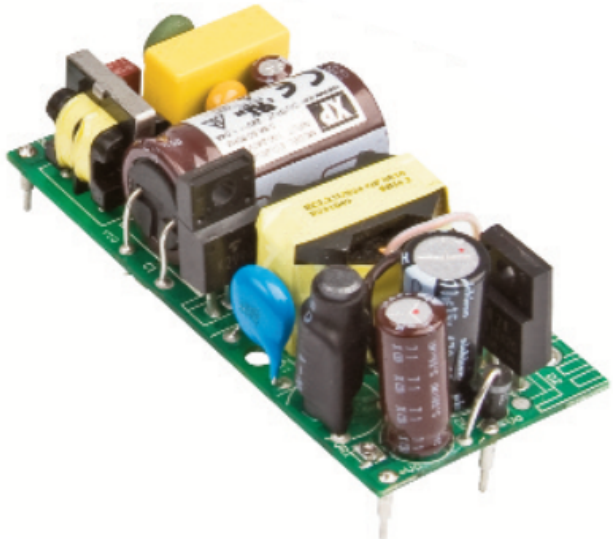
Operating Temperature	• -25 °C to +70 °C, see derating curve
Cooling	• Convection cooled
Operating Humidity	• 0-95% R.H, non-condensing
Storage Temperature	• -40 °C to +80 °C
Operating Altitude	• 3000 m
Shock	• ±3 x 30 g shocks in each plane, 30 g: 11 ms (±0.5 ms), half sine, compliant to EN60068-2-27 & EN60068-2-47
Vibration	• 10-500 Hz at 2 g sweep and endurance at resonance in all 3 planes. Conforms to EN60068-2-6

EMC & Safety

Emissions	• EN55022 Class B conducted & radiated
Harmonic Currents	• EN61000-3-2 class A
Voltage Flicker	• EN61000-3-3
ESD Immunity	• EN61000-4-2, level 3 Perf Criteria A
Radiated Immunity	• EN61000-4-3, level 3 Perf Criteria A
EFT/Burst	• EN61000-4-4, level 3 Perf Criteria A (note 3)
Surge	• EN61000-4-5, installation Class 3, Perf Criteria A
Conducted Immunity	• EN61000-4-6, level 3 Perf Criteria A
Dips & Interruptions	• EN61000-4-11, 30% 10 ms, 60% 100 ms, 100% 5000 ms, Perf Criteria A, B, B
Safety Approvals	• IEC60950-1, CSA C22.2 No.60950-1-03, UL60950-1, TUV EN60950-1

Switch-mode power supplies (open frame)





Switch-mode power supplies (PCB mount)

UL 60950-1

Features

- AC/DC power modules for PCB mounting
- Highest power density
- Fully encapsulated plastic case
- Universal input 90–264 VAC, 47–440 Hz
- High efficiency
- EMI meets EN 55022, class B and FCC, level B
- Low ripple and noise
- Short circuit and overload protection
- 3-year product warranty

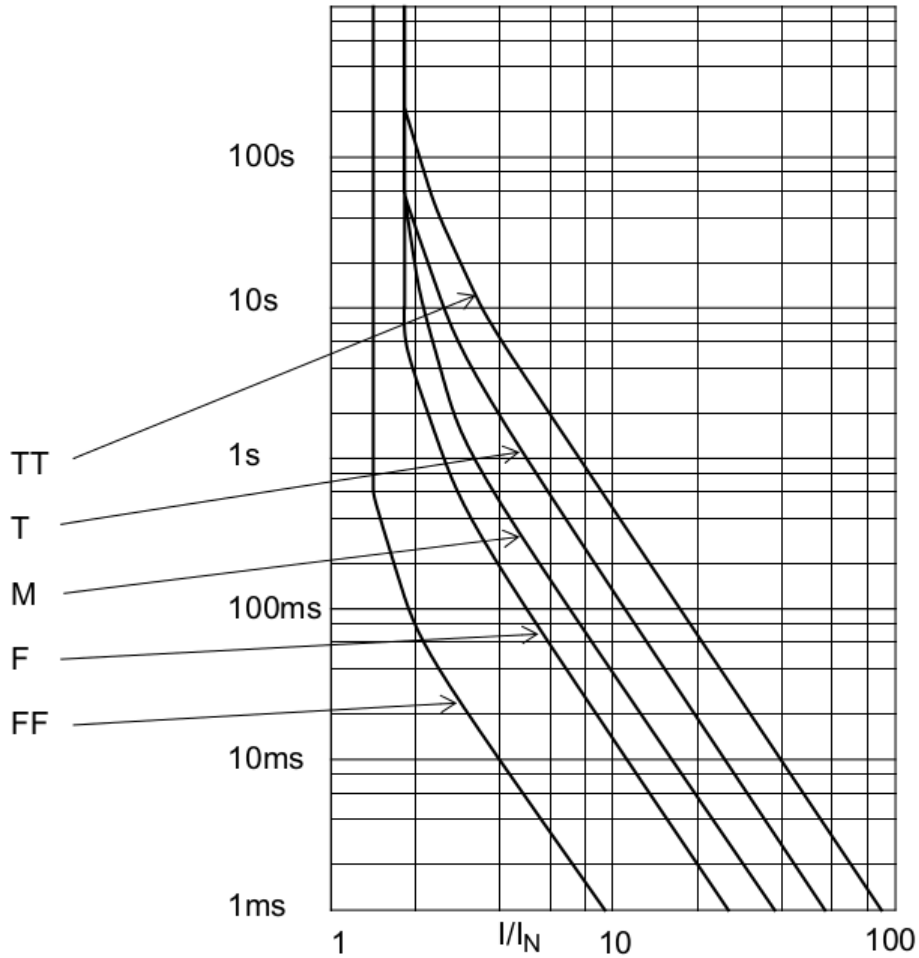
The TMLM Series switching power supplies, offer highest power density in a fully encapsulated module which can be soldered directly on to PCBs. This feature makes these modules an ideal solution for all space critical applications in commercial and industrial electronic equipment. International safety approvals qualify the product for worldwide markets. SMD-technology and high efficiency guarantees a high reliability of these Power Supplies.

Models

Order Code	Output Power max.	Output 1	Output 2	Efficiency
TMLM 04103	4.0 Watt	3.3 VDC / 1200 mA		68 %
TMLM 04105	4.0 Watt	5.0 VDC / 800 mA		72 %
TMLM 04109	4.0 Watt	9.0 VDC / 444 mA		75 %
TMLM 04112	4.0 Watt	12 VDC / 333 mA		76 %
TMLM 04115	4.0 Watt	15 VDC / 267 mA		76 %
TMLM 04124	4.0 Watt	24 VDC / 167 mA		77 %
TMLM 04253	3.5 Watt	+5.0 VDC / 600 mA	+3.3 VDC / 150 mA	72 %
TMLM 04225	3.6 Watt	+12 VDC / 250 mA	+5.0 VDC / 120 mA	75 %

Fuses

Typical time-current curves



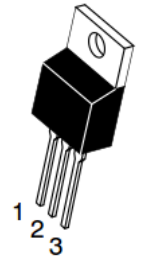
Source: The Circuit Designer's Companion

78XX, 78LXX

1.0 A Positive Voltage Regulators

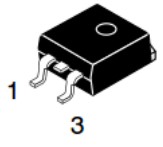
These voltage regulators are monolithic integrated circuits designed as fixed−voltage regulators for a wide variety of applications including local, on−card regulation. These regulators employ internal current limiting, thermal shutdown, and safe−area compensation. With adequate heatsinking they can deliver output currents in excess of 1.0 A. Although designed primarily as a fixed voltage regulator, these devices can be used with external components to obtain adjustable voltages and currents.

- Output Current in Excess of 1.0 A
- No External Components Required
- Internal Thermal Overload Protection
- Internal Short Circuit Current Limiting
- Output Transistor Safe−Area Compensation
- Output Voltage Offered in 1.5%, 2% and 4% Tolerance
- Available in Surface Mount D^2PAK−3, DPAK−3 and Standard 3−Lead Transistor Packages



TO−220−3
T SUFFIX
CASE 221AB

Heatsink surface connected to Pin 2.



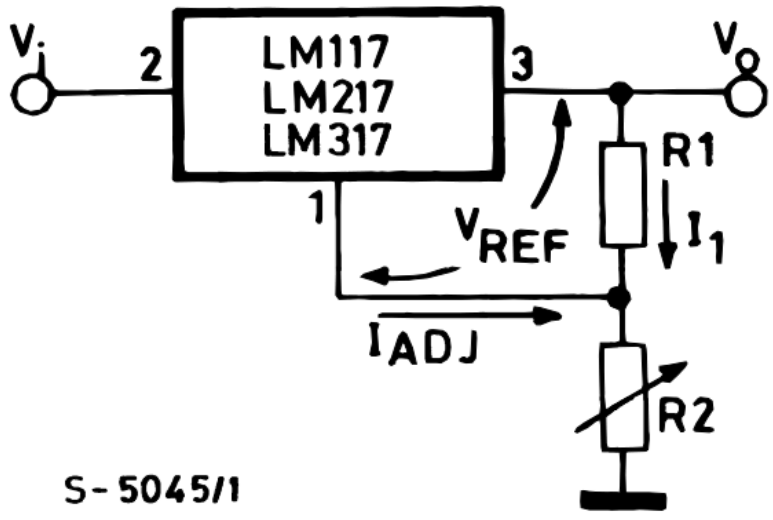
Pin 1. Input
2. Ground
3. Output

D^2PAK−3
D2T SUFFIX
CASE 936

Heatsink surface (shown as terminal 4 in case outline drawing) is connected to Pin 2.

7805 Datasheet

LM317 adjustable regulator



- $V_O = V_{REF}(1 + R2/R1) + I_{ADJ}R2$
- $I_{ADJ} \approx 100\ \mu$A

LM317 Datasheet

LDO linear regulators

LP38691
LP38693 500mA Low Dropout CMOS Linear Regulators
Stable with Ceramic Output Capacitors

Check for Samples: LP38691, LP38693

FEATURES

- All WSON Options are Available as AEC-Q100 Grade 1
- 2.0% Output Accuracy (25°C)
- Low Dropout Voltage: 250 mV @ 500mA (typ, 5V out)
- Wide Input Voltage Range (2.7V to 10V)
- Precision (Trimmed) Bandgap Reference
- Ensured Specs for -40°C to +125°C
- 1µA Off-State Quiescent Current
- Thermal Overload Protection
- Foldback Current Limiting
- PFM, SOT-223 and 6-Lead WSON Packages
- Enable Pin (LP38693)

APPLICATIONS

- Hard Disk Drives
- Notebook Computers
- Battery Powered Devices
- Portable Instrumentation

DESCRIPTION

The LP38691/3 low dropout CMOS linear regulators provide tight output tolerance (2.0% typical), extremely low dropout voltage (250 mV @ 500mA load current, V_{OUT} = 5V), and excellent AC performance utilizing ultra low ESR ceramic output capacitors.

The low thermal resistance of the WSON, SOT-223 and PFM packages allow the full operating current to be used even in high ambient temperature environments.

The use of a PMOS power transistor means that no DC base drive current is required to bias it allowing ground pin current to remain below 100 µA regardless of load current, input voltage, or operating temperature.

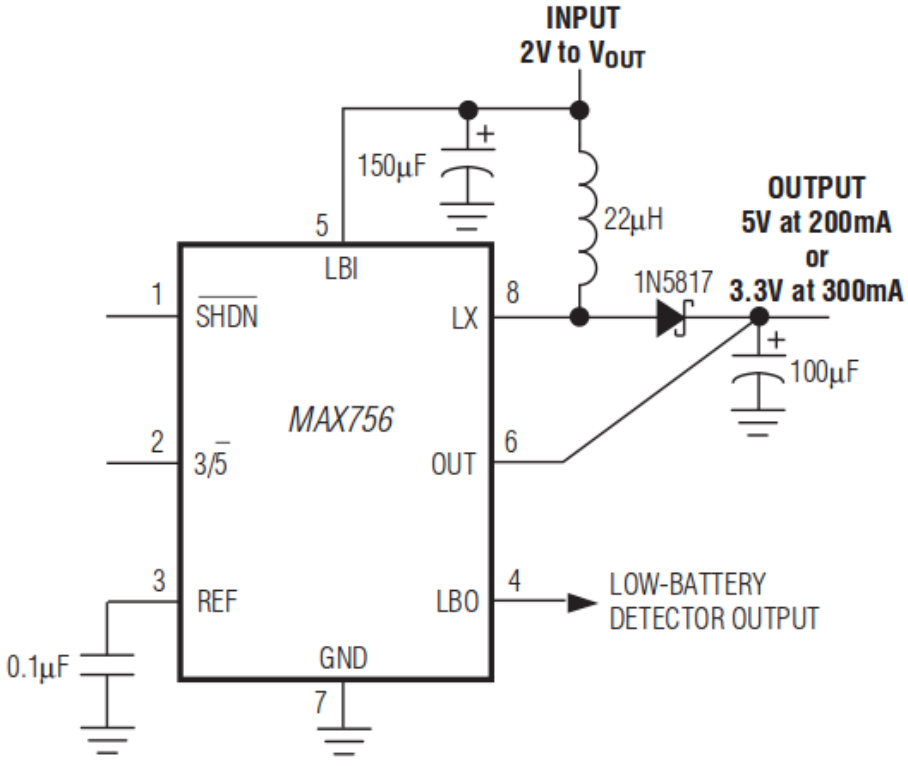
Dropout Voltage: 250 mV (typ) @ 500mA (typ. 5V out).

Ground Pin Current: 55 µA (typ) at full load.

Precision Output Voltage: 2.0% (25°C) accuracy.

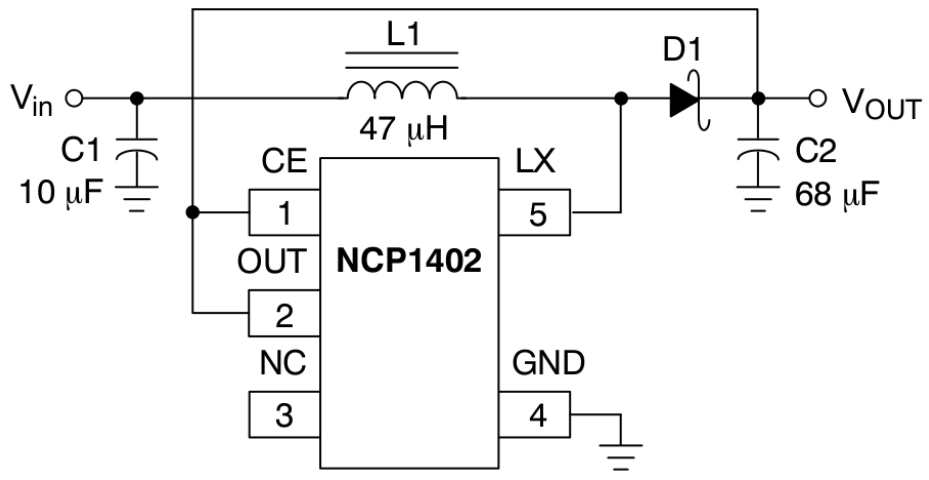
LP38691 Datasheet

MAX756 Step-Up DC-DC converter



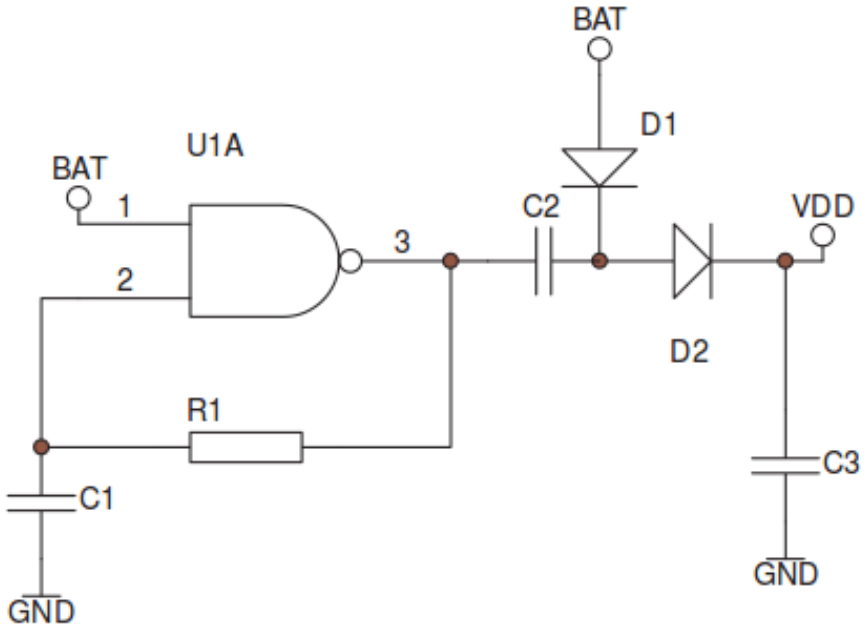
MAX756 Datasheet

NCP1402 Step-Up DC-DC converter



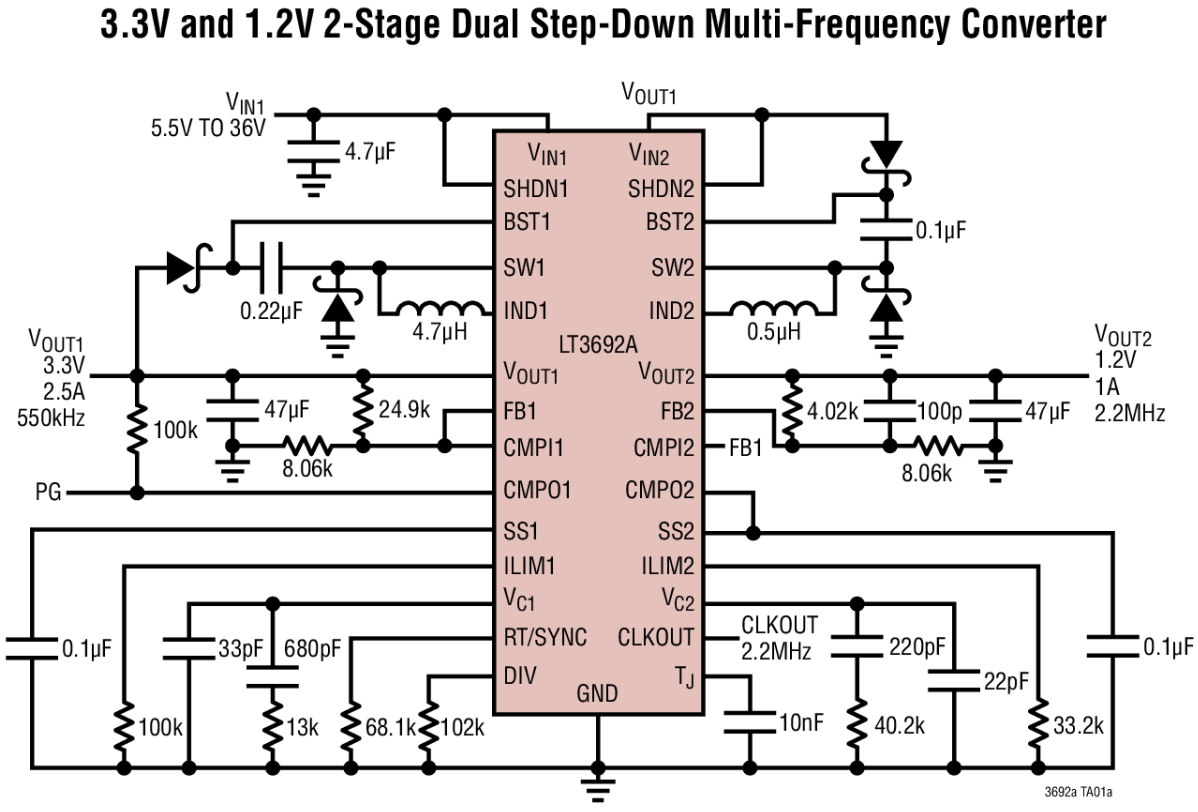
NCP1402 Datasheet

Voltage Doubler



Single cell power supply

LT3692a



- Monolithic Dual Tracking 3.5A Step-Down Switching Regulator
- Technical Note

LM2596

LM2596 SIMPLE SWITCHER® Power Converter 150-kHz 3-A Step-Down Voltage Regulator

1 Features

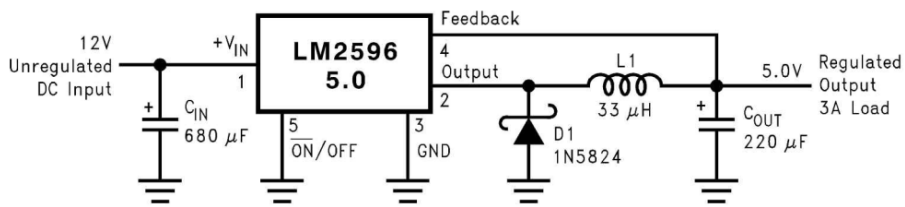
- New product available:
  - LMR51430 4.5 to 36-V, 3-A, 500-kHz and 1.1-MHz synchronous converter
- For faster time to market:
  - TLVM13630 3 to 36-V, 3-A, 200-kHz to 2.2-MHz power module
- 3.3-V, 5-V, 12-V, and adjustable output versions
- Adjustable version output voltage range: 1.2-V to 37-V ±4% maximum over line and load conditions
- Available in TO-220 and TO-263 packages
- 3-A output load current
- Input voltage range up to 40 V
- Requires only four external components
- Excellent line and load regulation specifications
- 150-kHz fixed-frequency internal oscillator
- TTL shutdown capability
- Low power standby mode, I_Q, typically 80 µA
- High efficiency
- Uses readily available standard inductors
- Thermal shutdown and current-limit protection
- Create a custom design using the LM2596 with the WEBENCH® Power Designer

3 Description

The LM2596 series of regulators are monolithic integrated circuits that provide all the active functions for a step-down (buck) switching regulator, capable of driving a 3-A load with excellent line and load regulation. These devices are available in fixed output voltages of 3.3 V, 5 V, 12 V, and an adjustable output version.

Requiring a minimum number of external components, these regulators are simple to use and include internal frequency compensation, and a fixed-frequency oscillator.

The LM2596 series operates at a switching frequency of 150 kHz, thus allowing smaller sized filter components than what can be required with lower frequency switching regulators. Available in a standard 5-pin TO-220 package with several different lead bend options, and a 5-pin TO-263 surface mount package.



Typical Application

3-A Step-Down Voltage Regulator

Batteries

- Electro-chemical reaction
- Anode (negative) and cathode (positive) terminals...
- ...separated by an electrolyte
- Voltage (time, temperature, history ...)
- Primary cells (non-rechargeable)
- Secondary cells (rechargeable)

Batteries and Accumulators Directive (91/157/EEC)

Design considerations

- Use standard types
- Voltage and capacity ratings
  - Nominal open circuit voltage
  - Real voltage falls as deployed
  - Capacity C (Ah, mAh)
- Discharge
  - Discharge rate: fraction of C
  - 1000 mAh battery discharged with constant 20 mA will last 50 hours
  - Discharge modes:
    - Constant R
    - Constant I
    - Constant $P = VI$

Series and parallel connections

- Series connection
  - Boost voltage
  - Less reliability
- Parallel connection
  - Increase capacity
  - More reliability (with series diodes)

Mechanical considerations

- Contact material: nickel-plates steel, stainless
- Springy contacts
- Multiple-point contacts
- Venting of gases

Some typical batteries

Alkaline manganese dioxide

Designation				Dimensions (mm)		
IEC	ANSI	Size	Voltage	Dia or (LxW)	Height	mAh*
LR03	24A	AAA	1.5	10.5	44.5	1150
LR6	15A	AA	1.5	14.5	50.5	2850
LR14	14A	C	1.5	26.2	50	7800
LR20	13A	D	1.5	34.2	61.5	15000
6LR61	1604A	PP3	9	26.5 x 17.5	48.5	580

Source: Duracell

Some typical batteries

Lithium manganese dioxide - coin cell

Designation				Dimensions (mm)		
IEC	ANSI	Size	Voltage	Dia or (LxW)	Height	mAh
CR2016	5000LC		3	20	1.6	90
CR2025	5003LC		3	20	2.5	165
CR2032	5004LC		3	20	3.2	230
CR2430	5011LC		3	24.5	3	280
CR2450	5029LC		3	24.5	5	560

CR 2016

CR 2025

CR 2032

CR 2450

Source: Varta

Some typical batteries

Silver oxide button cells

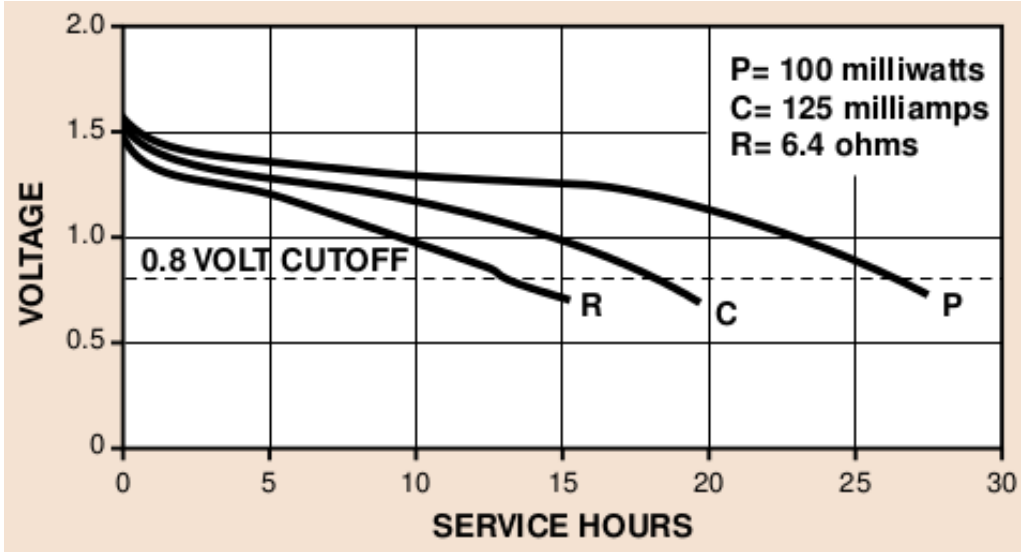
Designation				Dimensions (mm)		
IEC	ANSI	Size	Voltage	Dia or (LxW)	Height	mAh
SR41	1135S0		1.55	7.87	3.6	42
SR43	1133S0		1.55	11.56	4.19	120
SR44	1131S0		1.55	11.56	5.58	165
SR48	1137S0		1.55	7.87	5.38	70
SR54	1138S0		1.55	11.56	3.05	70
SR55	1160S0		1.55	11.56	2.21	40

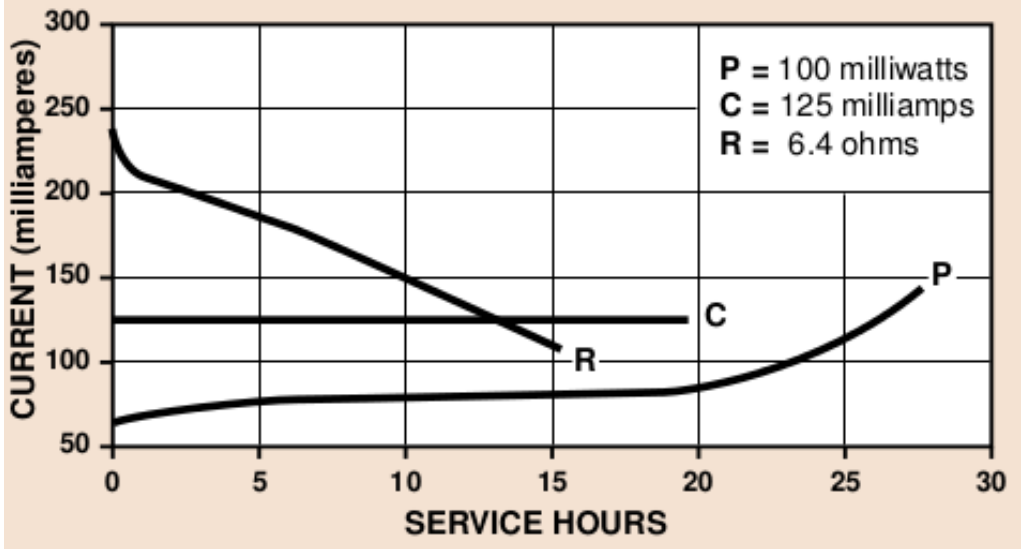
Energy density

Size	V	mAh	weight (g)	volume (ml)	Wh/kg	Wh/l
AAA	1.5	1150	11	4	126	345
AA	1.5	2850	24	8	143	428
C	1.5	7800	65	27	144	347
D	1.5	15000	138	56	130	322
PP3	9	580	46	23	91	182

Source: Duracell

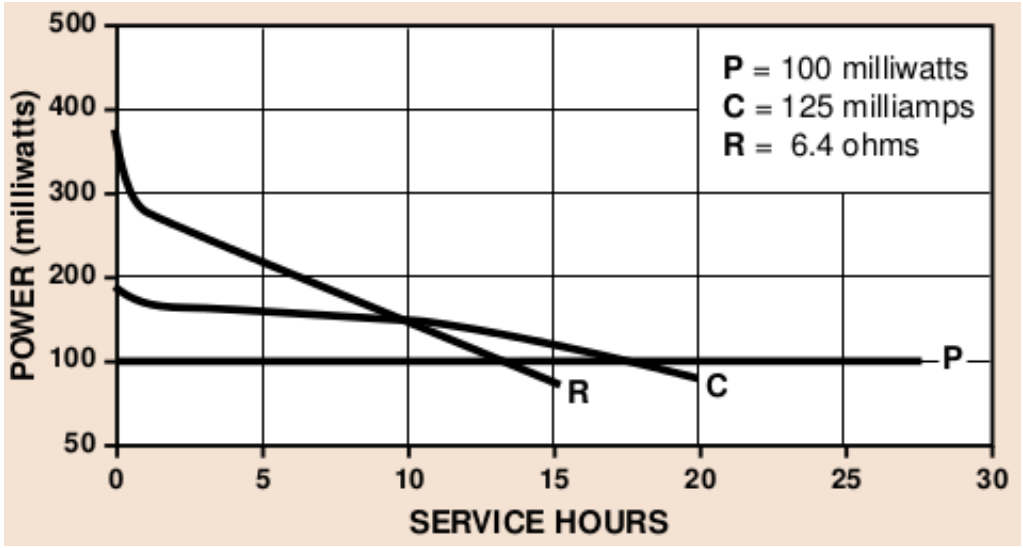
Discharge profiles



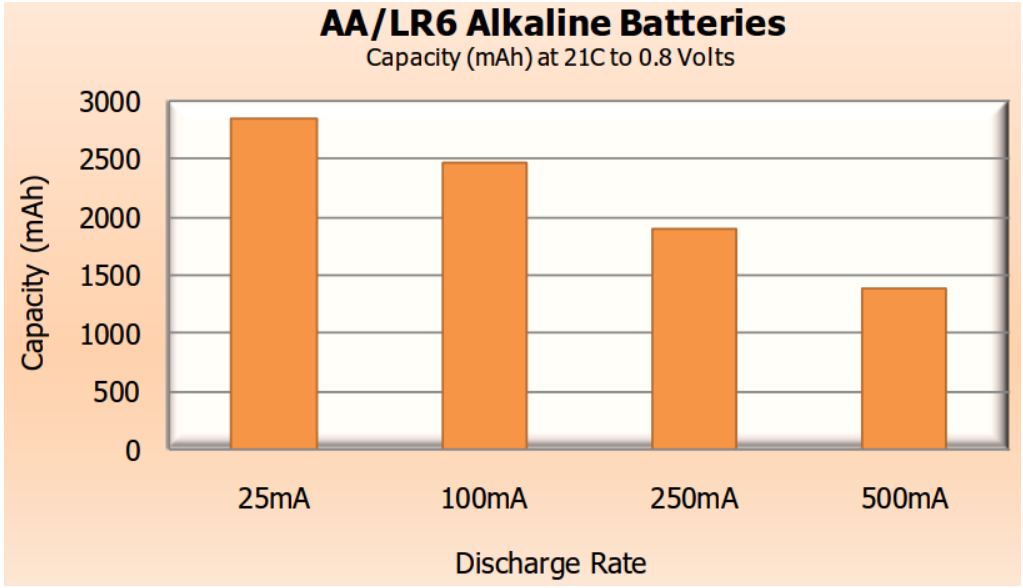


Source: Duracell

Discharge profiles /2



Source: Duracell



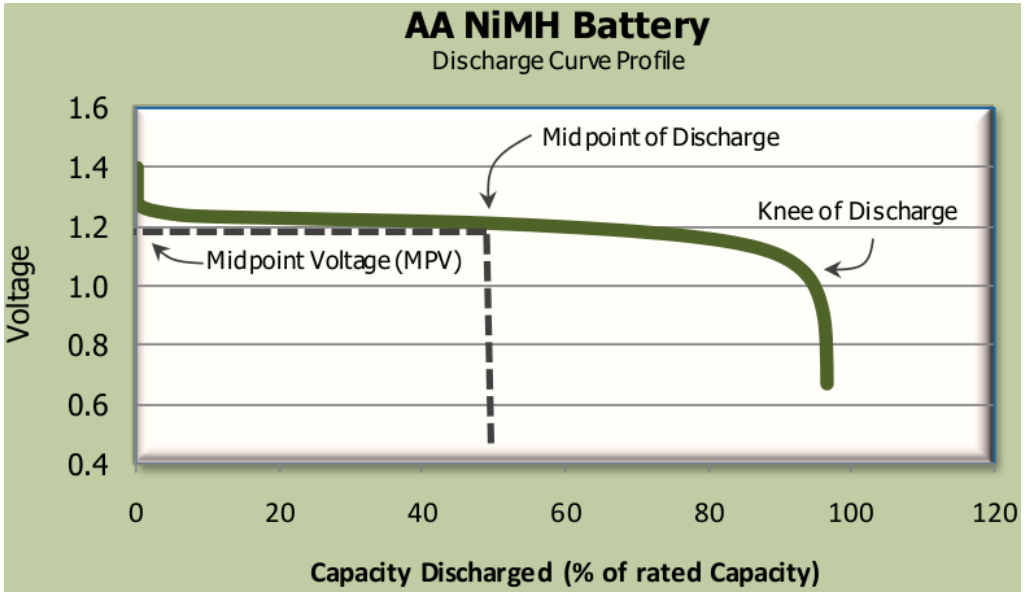
Source: Energizer

Secondary cells

- Lead-acid
  - Capacity 1–100 Ah
  - Nominal 2 V
  - Open circuit 2.15 V
  - End-of-cycle 1.75 V
  - Standard case sizes in 6 V or 12 V
- Nickel-cadmium
  - Capacity 150–7000 mAh
  - Nominal 1.2 V
  - Open circuit 1.35–1.4 V
  - End-of-cycle 1 V
  - Case sizes same as standard cells
  - Memory effect: better to fully discharge them
- Nickel-Metal-Hydride (NiMH)
- Lithium Ion

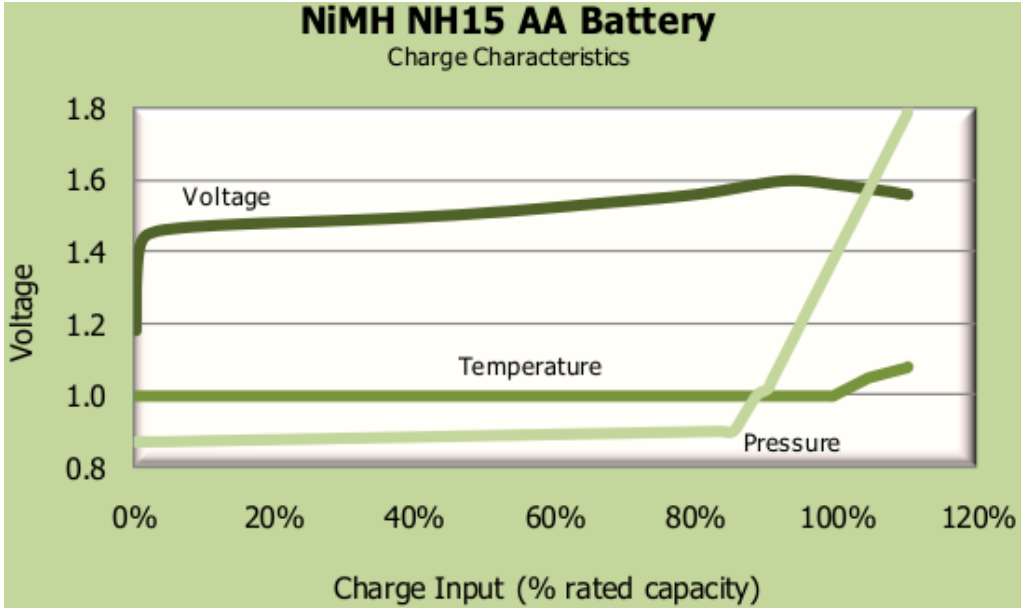
NiMH

- Capacity ($\times$1.4 NiCd). 1800 mAh (AA)
- Nominal 1.2 V, open circuit 1.35–1.4 V, end-of-cycle 1 V
- Case sizes same as standard cells
- No memory effects
- Low internal resistance
- PP3 (9V) batteries: 8.4 V (or 9.6 V), 200 mAh



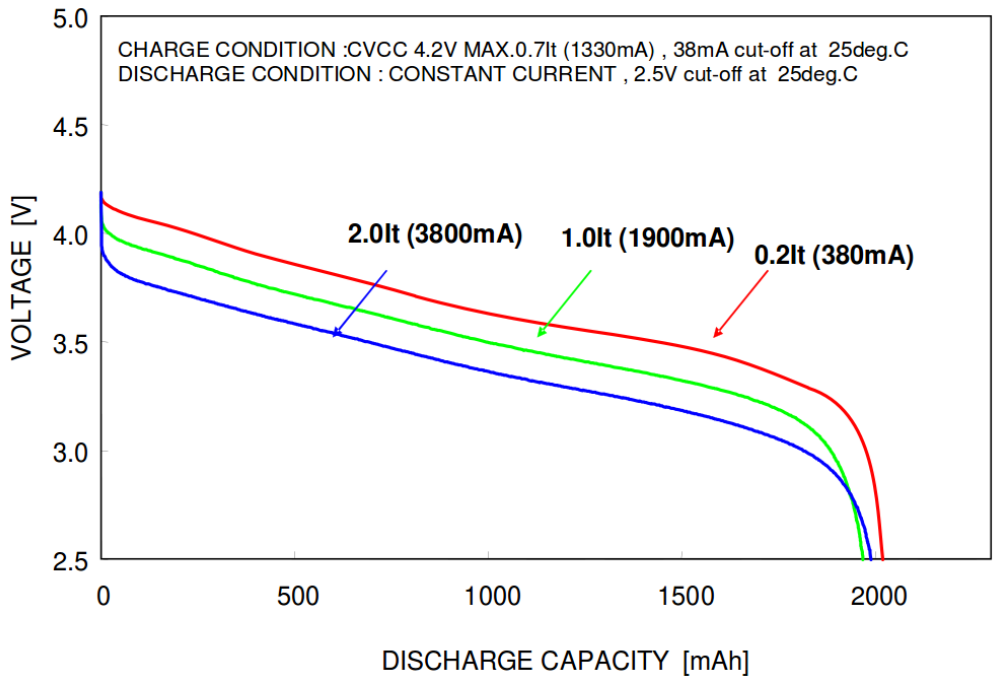
Charging NiMH

- Continuous charging up to 0.1 C is permissible. 16 hours.
- Timer-controlled at 0.3 C.
- Smart charging
  - Delta voltage. Drop of voltage during charge (15 mV)
  - Monitoring temperature
  - C/2 (2 to 3 hours) optimum
  - C only if really necessary
- Trickle charging ($< C/40$) to top off or maintain
- Self discharge: 50% in 6 months



Lithium ion

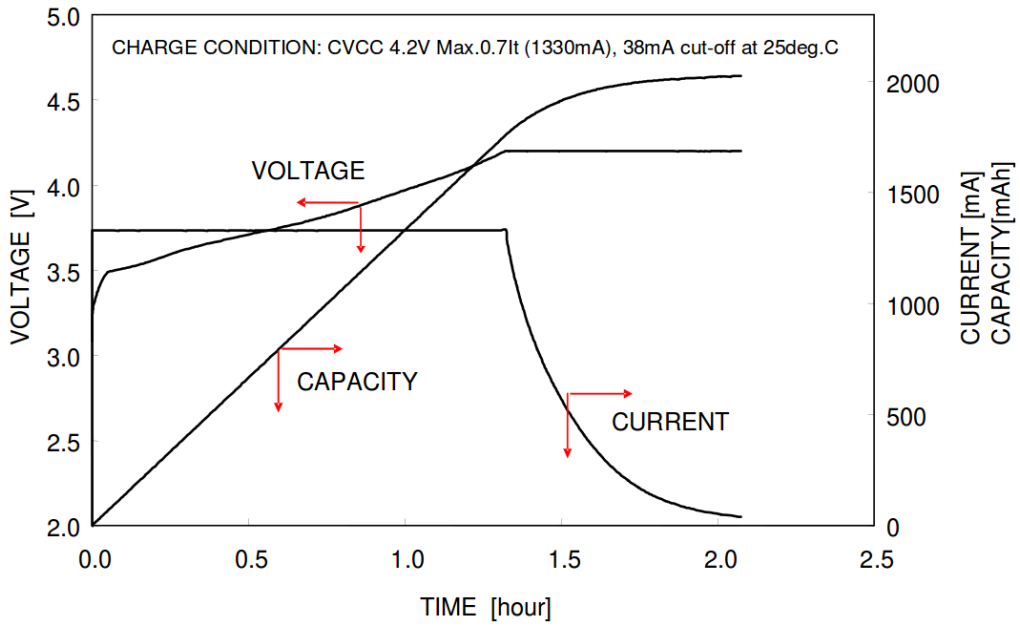
- Nominal 3.6 V or 3.7 V, open circuit 4.2 V or 4.3 V, end-of-cycle 2.5 V
- A variety of case sizes
- No memory effects
- High internal resistance



Source: Panasonic

Charging Lithium ion

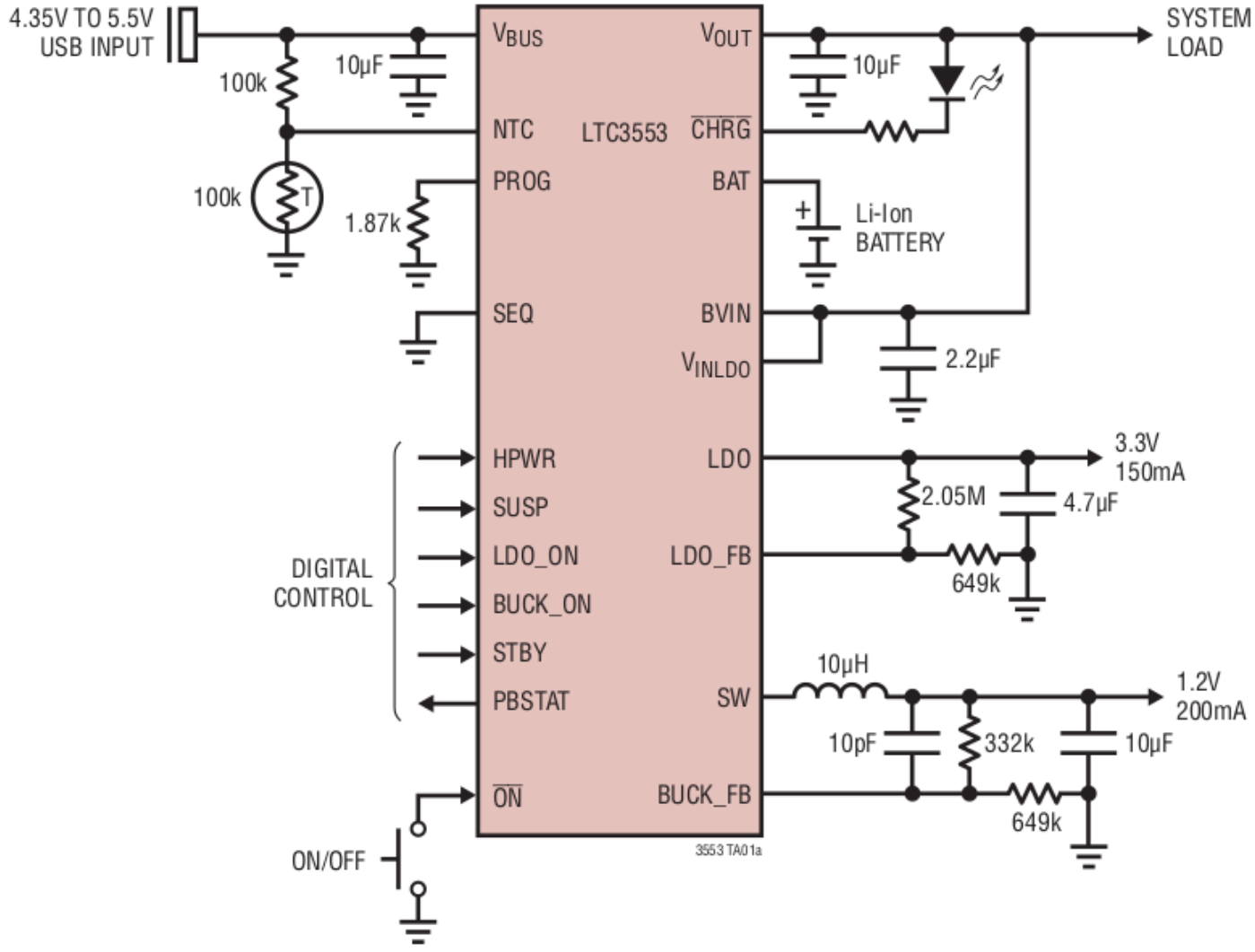
- Panasonic NCR18500 (2000 mAh)
- Constant current charging at 0.7 C until $v = 4.2$ V
- Constant voltage charging at 4.2 V until $i < 38$ mA
- Use 4.3 V for other cells. Current threshold as in datasheet!



Source: Panasonic

Lithium ion charge controller

LTC3553



Lithium Ion Standard Cells

18650

18mm x 650mm

Lithium Ion Standard Cells

2013 data

Panasonic

Lithium Ion

NCR18650

Features & Benefits

- High energy density
- Long stable power and long run time
- Ideal for notebook PCs, boosters, portable devises, etc.

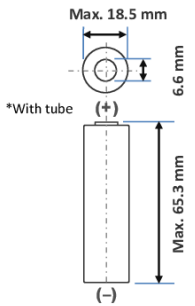
Specifications

Rated capacity(1)	Min. 2700mAh
Capacity(2)	Min. 2750mAh Typ. 2900mAh
Nominal voltage	3.6V
Charging	CC-CV, Std. 1925mA, 4.20V, 3.0 hrs
Weight (max.)	46.5 g
Temperature	Charge*: 0 to +45°C Discharge: -20 to +60°C Storage: -20 to +50°C
Energy density(3)	Volumetric: 577 Wh/l Gravimetric: 214 Wh/kg

* At temperatures below 10°C, charge at a 0.35C rate.

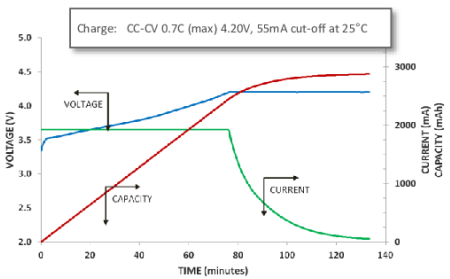
(1) At 20°C (2) At 25°C (3) Energy density based on bare cell dimensions

Dimensions

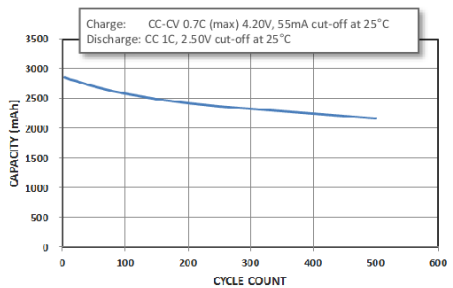


For Reference Only

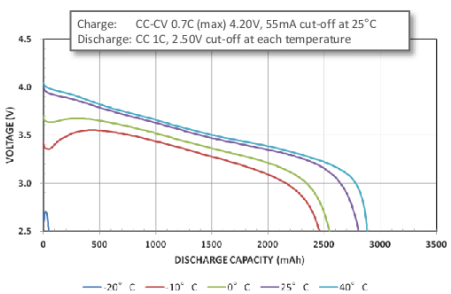
Charge Characteristics



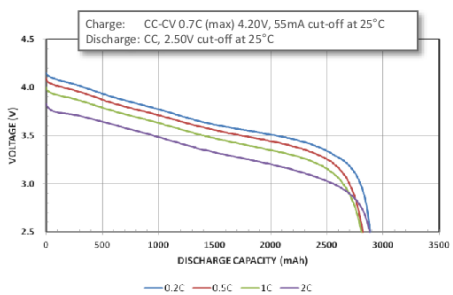
Cycle Life Characteristics



Discharge Characteristics (by temperature)



Discharge Characteristics (by rate of discharge)



Lithium Ion Standard Cells

2025 data

Specifications for NCR18650BD

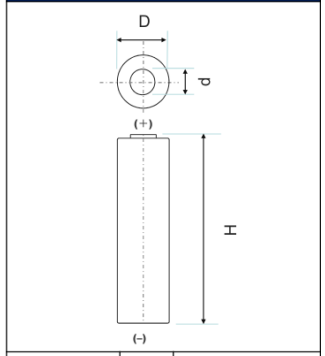
1

Specifications			
Rated capacity(1)		2980mAh	2910mAh
Capacity(2)	Minimum	3030mAh	2935mAh
	Typical	3180mAh	3080mAh
Nominal voltage		3.6V	
Charging	Method	CC-CV	
	Voltage	4.20V	4.15V
	Current	Std. 0.3CA	
Weight (max.) Without tube		49.5g	
Temperature	Charge	10 to +45° C	
	Discharge	-20 to +60° C	
	Storage	-20 to +50° C	
Energy density(3)	Volumetric	630 Wh/l	615 Wh/l
	Gravimetric	217 Wh/kg	212 Wh/kg

(1) At 20° C (2) At 25° C

(3) Energy density is calculated using bare cell dimensions (without tube).

Dimensions

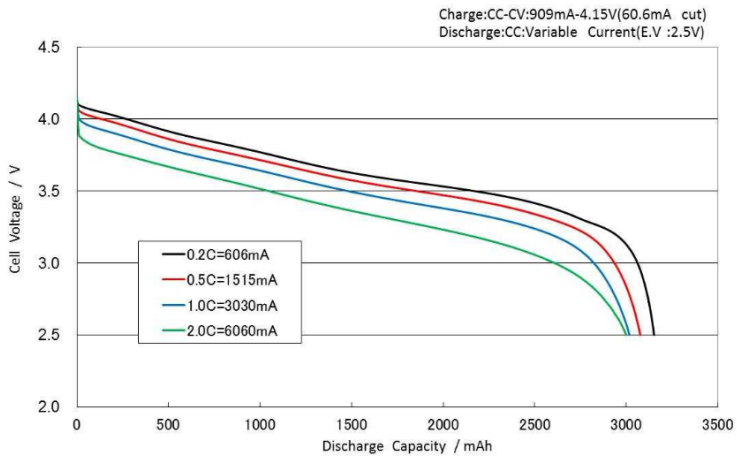


Without tube	H	Max. 65.10mm
	D	Max. 18.25mm
	d	Max. 6.6mm

When designing a pack, refer to the cell's mechanical drawing for precise dimensions.

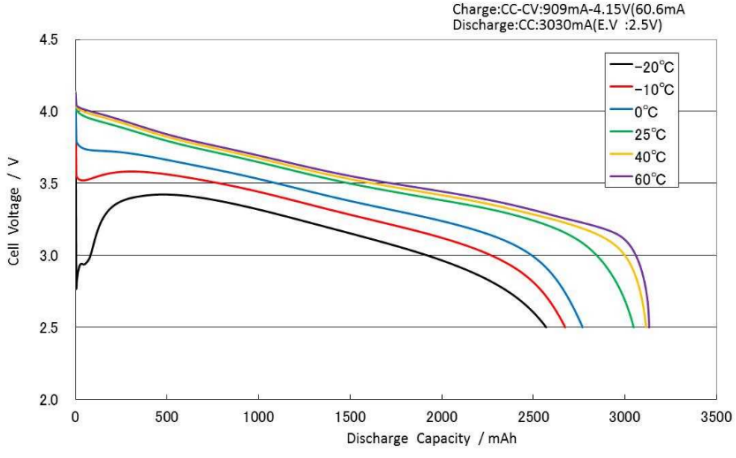
Discharge Rate Characteristics for NCR18650BD

2



Discharge Temperature Characteristics for NCR18650BD

3



Cycle Characteristics for NCR18650BD

4