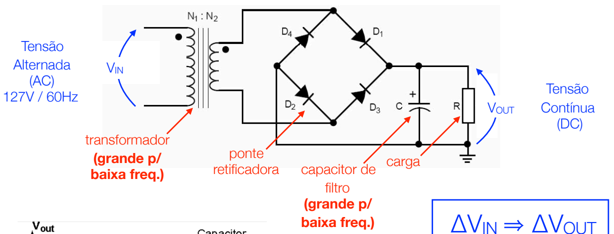
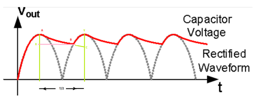
Baterias e Conversores DC-DC

Jun Okamoto Jr.

Revisão: Conversor AC-DC

- Fonte de alimentação não regulada





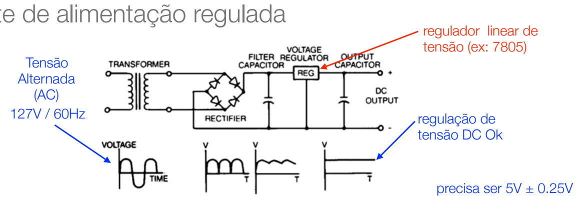
$\Delta V_{IN} \Rightarrow \Delta V_{OUT}$

$\Delta I_{OUT} \Rightarrow \Delta V_{OUT}$

https://electronics.stackexchange.com/questions/259063/confusion-in-deriving-ripple-voltage-for-an-unregulated-power-supply

Revisão: Conversor AC-DC

- Fonte de alimentação regulada



http://www.coreetronix.com/p/difference-between.html

precisa ser 5V ± 0.25V para alimentar TTL

recommended operating conditions (see Note 3)

		SN5400			SN7400			UNIT
		MIN	NOM	MAX	MIN	NOM	MAX	
V_{CC}	Supply voltage	4.5	5	5.5	4.75	5	5.25	V
V_{IH}	High-level input voltage	2			2			V
V_{IL}	Low-level input voltage			0.8			0.8	V
I_{OH}	High-level output current			–0.4			–0.4	mA
I_{OL}	Low-level output current			16			16	mA
T_A	Operating free-air temperature	–55		125	0		70	°C

NOTE 3: All unused inputs of the device must be held at V_{CC} or GND to ensure proper device operation. Refer to the TI application report, *Implications of Slow or Floating CMOS Inputs*, literature number SCBA004.

SN7400 data sheet

$\Delta V_{IN} \nRightarrow \Delta V_{OUT}$

$\Delta I_{OUT} \nRightarrow \Delta V_{OUT}$

Regulador linear de tensão (7805)

electrical characteristics at specified virtual junction temperature, V_I = 10 V, I_O = 500 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS	T_J†	µA7805C MIN	µA7805C TYP	µA7805C MAX	UNIT
Output voltage	I_O = 5 mA to 1 A, V_I = 7 V to 20 V, P_D ≤ 15 W	25°C	4.8	5	5.2	V
		0°C to 125°C	4.75		5.25	
Input voltage regulation	V_I = 7 V to 25 V	25°C		3	100	mV
	V_I = 8 V to 12 V			1	50	
Ripple rejection	V_I = 8 V to 18 V, f = 120 Hz	0°C to 125°C	62	78		dB
Output voltage regulation	I_O = 5 mA to 1.5 A	25°C		15	100	mV
	I_O = 250 mA to 750 mA			5	50	
Output resistance	f = 1 kHz	0°C to 125°C		0.017		Ω
Temperature coefficient of output voltage	I_O = 5 mA	0°C to 125°C		–1.1		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz	25°C		40		µV
Dropout voltage	I_O = 1 A	25°C		2		V
Bias current		25°C		4.2	8	mA
Bias current change	V_I = 7 V to 25 V	0°C to 125°C			1.3	mA
	I_O = 5 mA to 1 A				0.5	
Short-circuit output current		25°C		750		mA
Peak output current		25°C		2.2		A

† Pulse-testing techniques maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.33-µF capacitor across the input and a 0.1-µF capacitor across the output.

recommended operating conditions

			MIN	MAX	UNIT
V_I	Input voltage	µA7805C	7	25	V
		µA7808C	10.5	25	
		µA7810C	12.5	28	
		µA7812C	14.5	30	
		µA7815C	17.5	30	
		µA7824C	27	38	
I_O	Output current			1.5	A
T_J	Operating virtual junction temperature	µA7800C series	0	125	°C

µA7800 data sheet

Regulador linear de tensão (7805)

electrical characteristics at specified virtual junction temperature, V_I = 10 V, I_O = 500 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS	T_J†	µA7805C MIN	µA7805C TYP	µA7805C MAX	UNIT
Output voltage	I_O = 5 mA to 1 A, V_I = 7 V to 20 V, P_D ≤ 15 W	25°C	4.8	5	5.2	V
		0°C to 125°C	4.75		5.25	
Input voltage regulation	V_I = 7 V to 25 V	25°C		3	100	mV
	V_I = 8 V to 12 V			1	50	
Ripple rejection	V_I = 8 V to 18 V, f = 120 Hz	0°C to 125°C	62	78		dB
Output voltage regulation	I_O = 5 mA to 1.5 A	25°C		15	100	mV
	I_O = 250 mA to 750 mA			5	50	
Output resistance	f = 1 kHz	0°C to 125°C		0.017		Ω
Temperature coefficient of output voltage	I_O = 5 mA	0°C to 125°C		–1.1		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz	25°C		40		µV
Dropout voltage	I_O = 1 A	25°C		2		V
Bias current		25°C		4.2	8	mA
Bias current change	V_I = 7 V to 25 V	0°C to 125°C			1.3	mA
	I_O = 5 mA to 1 A				0.5	
Short-circuit output current		25°C		750		mA
Peak output current		25°C		2.2		A

† Pulse-testing techniques maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.33-µF capacitor across the input and a 0.1-µF capacitor across the output.

Ok para TTL

recommended operating conditions

			MIN	MAX	UNIT
V_I	Input voltage	µA7805C	7	25	V
		µA7808C	10.5	25	
		µA7810C	12.5	28	
		µA7812C	14.5	30	
		µA7815C	17.5	30	
		µA7824C	27	38	
I_O	Output current			1.5	A
T_J	Operating virtual junction temperature	µA7800C series	0	125	°C

µA7800 data sheet

Regulador linear de tensão (7805)

electrical characteristics at specified virtual junction temperature, V_I = 10 V, I_O = 500 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS	T_J†	µA7805C MIN	µA7805C TYP	µA7805C MAX	UNIT
Output voltage	I_O = 5 mA to 1 A, V_I = 7 V to 20 V, P_D ≤ 15 W	25°C	4.8	5	5.2	V
		0°C to 125°C	4.75		5.25	
Input voltage regulation	V_I = 7 V to 25 V	25°C		3	100	mV
	V_I = 8 V to 12 V			1	50	
Ripple rejection	V_I = 8 V to 18 V, f = 120 Hz	0°C to 125°C	62	78		dB
Output voltage regulation	I_O = 5 mA to 1.5 A	25°C		15	100	mV
	I_O = 250 mA to 750 mA			5	50	
Output resistance	f = 1 kHz	0°C to 125°C		0.017		Ω
Temperature coefficient of output voltage	I_O = 5 mA	0°C to 125°C		–1.1		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz	25°C		40		µV
Dropout voltage	I_O = 1 A	25°C		2		V
Bias current		25°C		4.2	8	mA
Bias current change	V_I = 7 V to 25 V	0°C to 125°C			1.3	mA
	I_O = 5 mA to 1 A				0.5	
Short-circuit output current		25°C		750		mA
Peak output current		25°C		2.2		A

† Pulse-testing techniques maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.33-µF capacitor across the input and a 0.1-µF capacitor across the output.

Ok para TTL

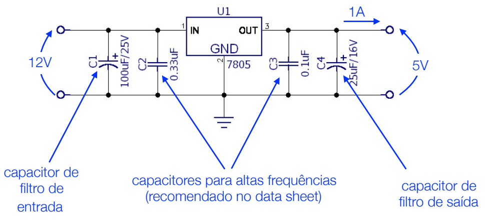
recommended operating conditions

			MIN	MAX	UNIT
V_I	Input voltage	µA7805C	7	25	V
		µA7808C	10.5	25	
		µA7810C	12.5	28	
		µA7812C	14.5	30	
		µA7815C	17.5	30	
		µA7824C	27	38	
I_O	Output current			1.5	A
T_J	Operating virtual junction temperature	µA7800C series	0	125	°C

Atenção para as tensões mínima e máxima de entrada (12V → Ok)

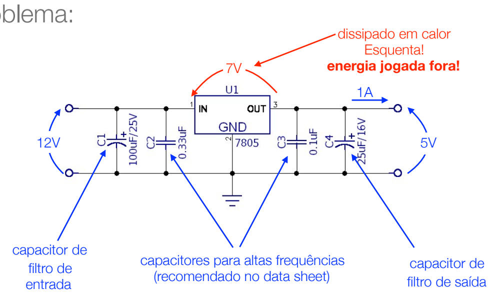
µA7800 data sheet

Regulador linear de tensão (7805)



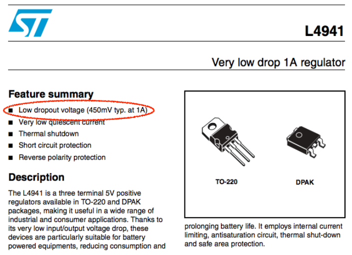
Regulador linear de tensão (7805)

- O problema:



Regulador linear de tensão (7805)

- As soluções:
  - Baixar a tensão de entrada p/ o mínimo: 7V
    - Mesmo assim fica queda de tensão de 2V sobre o 7805
  - Baixar a tensão de entrada para 5.5V no mínimo e usar um Low Dropout (LDO)
  - Usar outra coisa:
    - Fonte chaveada



L4941

Very low drop 1A regulator

Feature summary

- Low dropout voltage (450mV typ. at 1A)
- Very low quiescent current
- Thermal shutdown
- Short circuit protection
- Reverse polarity protection

Description

The L4941 is a three terminal 5V positive regulators available in TO-220 and DPAK packages, making it useful in a wide range of industrial and consumer applications. Thanks to its very low input/output voltage drop, these devices are particularly suitable for battery powered equipments, reducing consumption and prolonging battery life. It employs internal current limiting, antisaturation circuit, thermal shut-down and safe area protection.

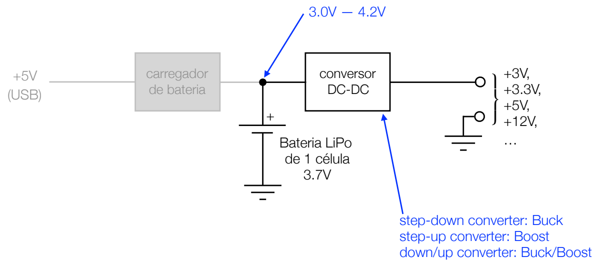
L4941 data sheet

Fonte chaveada

- Trabalha em alta frequência
  - Reduz o tamanho do transformador e do capacitor
- Eficiência de 80-95% (típico)
- Ótima regulação de tensão e corrente
- Projeto mais complexo
- Maior custo do que fontes lineares

Usando conversores DC-DC

- Sistema de alimentação por bateria



Baterias

- Algumas características

Química	Voltagem da célula	Auto-descarga	Memória	Número de ciclos	Temperatura	Peso
(1) Alcalina	1.5V	<0.3% / mês	n/a	n/a	-15°C ~ 55°C	médio
(2) Li/MnO_2	3.0V	0.5% / ano	n/a	n/a	-30°C ~ 60°C	muito leve
NiCd	1.2V	20% / mês	sim	< 800	-20°C ~ 60°C	pesado
NiMH	1.2V	30% / mês	um pouco	< 500	-20°C ~ 70°C	médio
Chumbo - ácido	2.1V	3-20% / mês	não	< 350	-35°C ~ 45°C	pesado
Li-ion	3.6V	5-10% / mês	não	500-1000	-40°C ~ 70°C	leve
(3) LiPo	3.7V	5-10% / mês	não	500-1000	-40°C ~ 80°C	muito leve

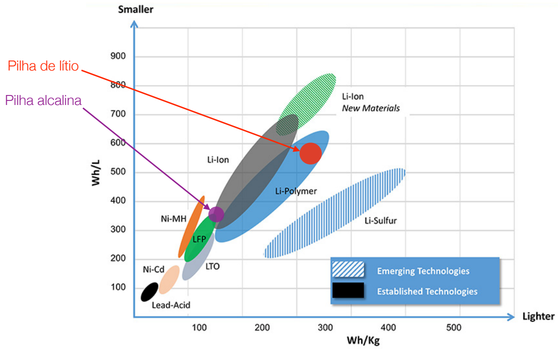
(1) 

(2) 

(3) 

Baterias

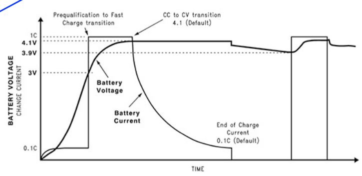
- Densidade de energia



http://inventuspower.com/lithium-ion-power-for-data-storage-and-servers/

Baterias LiPo

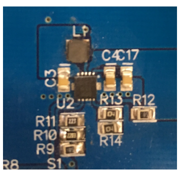
- Tensão de caga: < 4.2V
- Tensão de operação: > 3.0V
- Necessário proteção para:
  - sobre-carregamento (overcharge) (no carregador)
  - sobre-descarga (over-discharge) (na bateria)
  - sobre-temperatura (no carregador)
  - curto-circuito (na bateria)
- Carregador específico para LiPo e Li-ion



https://www.digikey.com/en/articles/techzone/2016/sep/a-designer-guide-fast-lithium-ion-battery-charging

Conversores DC-DC

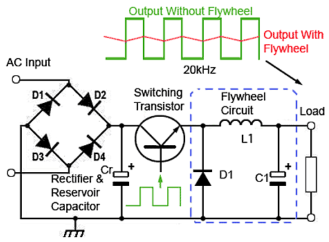
- Podem ser step-down (Buck), step-up (Boost), step-down/step-up (Buck/Boost)
- Alta eficiência (tip. > 80%)
- Ótima regulação de tensão e corrente
- Compacto (CIs dedicados com elemento de potência incluído, indutor externo)



Conversor DC-DC do Robô

Conversor Buck

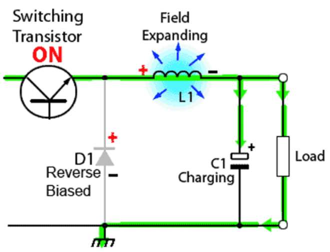
- Circuito básico



http://www.learnabout-electronics.org/PSU/psu31.php

Conversor Buck

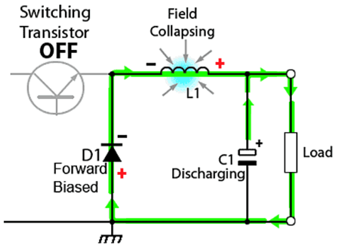
- Funcionamento



http://www.learnabout-electronics.org/PSU/psu31.php

Conversor Buck

- Funcionamento



http://www.learnabout-electronics.org/PSU/psu31.php

Conversor BUCK

- Tensão de saída

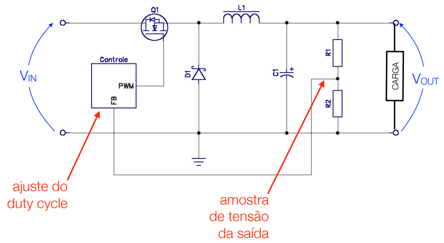
$$V_{OUT} = V_{IN} \frac{t_{ON}}{T}$$

  - t_{ON} é o tempo do transistor ligado e T é o periodo do PWM

- Exemplo:
  - V_{IN} = 9V, T = 10µs, t_{ON} = 1µs (10% de PWM) ⇒ V_{OUT} = 0.9V
  - V_{IN} = 9V, T = 10µs, t_{ON} = 5µs (50% de PWM) ⇒ V_{OUT} = 4.5V
  - V_{IN} = 9V, T = 10µs, t_{ON} = 9µs (90% de PWM) ⇒ V_{OUT} = 8.1V

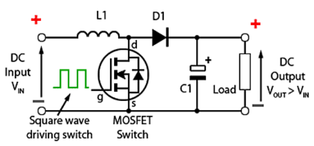
Conversor Buck

- Regulação automática de V_{OUT}



Conversor Boost

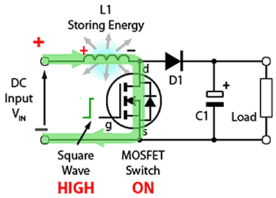
- Circuito básico



http://www.learnabout-electronics.org/PSU/psu32.php

Conversor Boost

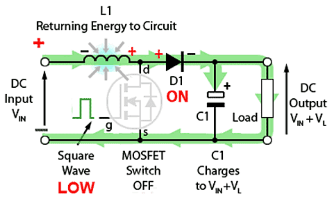
- Funcionamento



http://www.learnabout-electronics.org/PSU/psu32.php

Conversor Boost

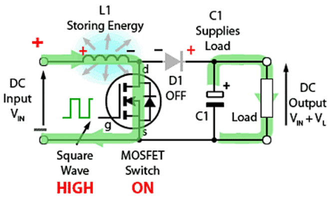
- Funcionamento



http://www.learnabout-electronics.org/PSU/psu32.php

Conversor Boost

- Funcionamento



http://www.learnabout-electronics.org/PSU/psu32.php

Conversor Boost

- Tensão de saída

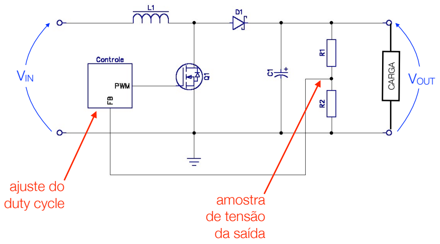
$$V_{OUT} = \frac{V_{IN}}{(1 - t_{ON}/T)}$$

  - t_{ON} é o tempo do transistor ligado e T é o periodo do PWM

- Exemplo:
  - $V_{IN} = 9V$, $T = 10\mu s$, $t_{ON} = 1\mu s$ (10% de PWM) ⇒ $V_{OUT} = 10V$
  - $V_{IN} = 9V$, $T = 10\mu s$, $t_{ON} = 5\mu s$ (50% de PWM) ⇒ $V_{OUT} = 18V$
  - $V_{IN} = 9V$, $T = 10\mu s$, $t_{ON} = 9\mu s$ (90% de PWM) ⇒ $V_{OUT} = 90V$!

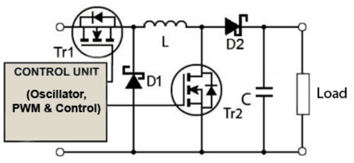
Conversor Boost

- Regulação automática de V_{OUT}



Conversor Buck-Boost

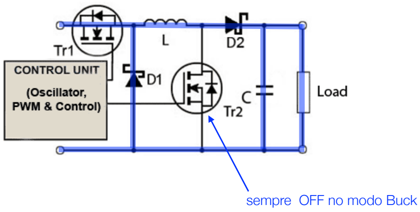
- Circuito básico



http://www.learnabout-electronics.org/PSU/psu33.php

Conversor Buck-Boost

- Circuito básico

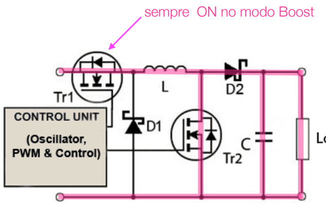


Modo Buck

http://www.learnabout-electronics.org/PSU/psu33.php

Conversor Buck-Boost

- Circuito básico

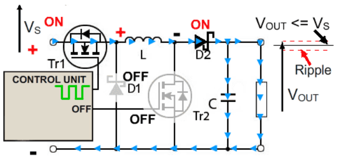


Modo Boost

http://www.learnabout-electronics.org/PSU/psu33.php

Conversor Buck-Boost

- Funcionamento

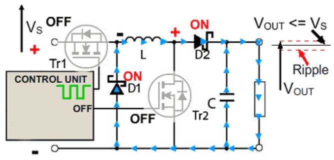


Modo Buck

http://www.learnabout-electronics.org/PSU/psu33.php

Conversor Buck-Boost

- Funcionamento

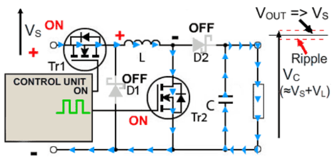


Modo Buck

http://www.learnabout-electronics.org/PSU/psu33.php

Conversor Buck-Boost

- Funcionamento

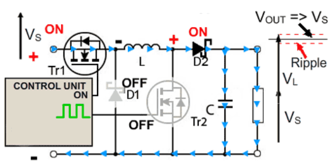


Modo Boost

http://www.learnabout-electronics.org/PSU/psu33.php

Conversor Buck-Boost

- Funcionamento



Modo Boost

http://www.learnabout-electronics.org/PSU/psu33.php

Exemplo

TEXAS INSTRUMENTS

TPS63030
TPS63031

www.ti.com SLVS696B – OCTOBER 2008 – REVISED MARCH 2012

HIGH EFFICIENCY SINGLE INDUCTOR BUCK-BOOST CONVERTER WITH 1-A SWITCHES

Check for Samples: TPS63030, TPS63031

FEATURES

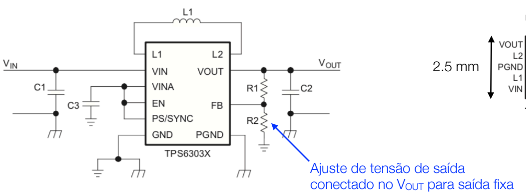
- Up to 96% Efficiency
- 800-mA Output Current at 3.3V in Step Down Mode (VIN = 3.6V to 5.5V)
- Up to 500-mA Output Current at 3.3V in Boost Mode (VIN > 2.4V)
- Automatic Transition Between Step Down and Boost Mode
- Device Quiescent Current less than 50μA
- Input Voltage Range: 1.8V to 5.5V
- Fixed and Adjustable Output Voltage Options from 1.2V to 5.5V
- Power Save Mode for Improved Efficiency at Low Output Power
- Forced Fixed Frequency Operation and Synchronization Possible
- Load Disconnect During Shutdown
- Over-Temperature Protection
- Available in Small 2.5mm × 2.5mm, QFN-10 Package

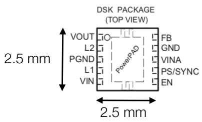
APPLICATIONS

- All Two-Cell and Three-Cell Alkaline, NiCd or NiMH or Single-Cell Li Battery Powered Products
- Portable Audio Players
- PDAs
- Cellular Phones
- Personal Medical Products
- White LEDs

TPS63030	saída ajustável
TPS63031	saída de 3.3V

Exemplo





Pin NAME	Pin NO.	I/O	DESCRIPTION
EN	6	I	Enable input. (1 enabled, 0 disabled)
FB	10	I	Voltage feedback of adjustable versions, must be connected to VOUT on fixed output voltage versions
GND	9		Control / logic ground
PS/SYNC	7	I	Enable / disable power save mode (1 disabled, 0 enabled, clock signal for synchronization)
L1	4	I	Connection for Inductor
L2	2	I	Connection for Inductor
PGND	3		Power ground
VIN	5	I	Supply voltage for power stage
VOUT	1	O	Buck-boost converter output
VINA	8	I	Supply voltage for control stage
PowerPAD™			Must be soldered to achieve appropriate power dissipation. Should be connected to PGND.

Projeto

- Programação da tensão de saída

$$R_1 = R_2 \times \left(\frac{V_{OUT}}{V_{FB}} - 1 \right)$$

  - V_{OUT} é a tensão desejada na saída (no máximo 5.5V)
  - V_{FB} é 500 mV (= tensão em R_2)
  - A corrente típica em FB é 0.01 μA
  - O valor recomendado de R_2 deve ser < 500kΩ para que a corrente no divisor seja > 1 μA (recomendado 100 x maior do que a corrente em FB)
  - É recomendado que R2 seja da ordem de 200kΩ

Projeto

- Seleção do valor indutor

$$L_1 = (V_{IN1} - V_{OUT}) \times 0.5 \times \frac{\mu s}{A}$$

  - L_1 é o valor mínimo da indutância para modo Buck
    V_{IN1} é a tensão máxima da entrada

$$L_2 = V_{OUT} \times 0.5 \times \frac{\mu s}{A}$$

  - L_2 é o valor mínimo da indutância para o modo Boost
  - A indutância mínima é o maior entre L_1 e L_2

Projeto

- Determinação da corrente de pico em regime sobre o indutor

$$I_1 = \frac{I_{OUT}}{0.8} + \frac{V_{OUT}(V_{IN1} - V_{OUT})}{2 \times V_{IN1} \times f \times L}$$

$$I_2 = \frac{V_{OUT} \times I_{OUT}}{0.8 \times V_{IN2}} + \frac{V_{IN2} \times (V_{OUT} - V_{IN2})}{2 \times V_{OUT} \times f \times L}$$

  - I_1 é a corrente em modo Buck
  - I_2 é a corrente em modo Boost
  - f é frequência de chaveamento
  - V_{IN2} é a tensão mínima da entrada
  - O valor da corrente crítica é o maior entre I_1 e I_2

Projeto

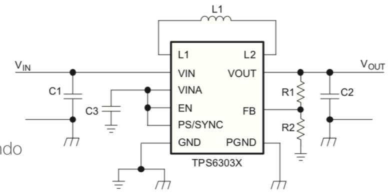
- O capacitor de entrada deve ser ≥ 4.7 μF
  - Um capacitor cerâmico deve ser colocado o mais próximo possível dos pinos VIN e PGND
- Capacitor entre VINA e GND deve ser cerâmico de 0.1 μF
  - O valor desse capacitor deve ser ≤ 0.22 μF
- O valor mínimo do capacitor de saída pode ser calculado por:

$$C_{OUT} = 5 \times L \times \frac{\mu F}{\mu H}$$

  - Esse capacitor deve ser colocado o mais próximo possível dos pino VOUT e PGND

Exercício

- Para um conversor TPS63030 operando com tensão de entrada entre 3,0V e 5,0V para fornecer uma saída de 4.2V
  - Calcular os valores de R_1, R_2, L_1 e C_2
  - Calcular a corrente crítica sobre o indutor
  - Escolher um indutor analisando os data sheet fornecidos
  - Sabe-se que a sua frequência de oscilação é de 2400 kHz



- Dica: Estude o procedimento de projeto no data sheet do componente que está nas páginas 15 e 16 para entender os motivos das escolhas do valores.