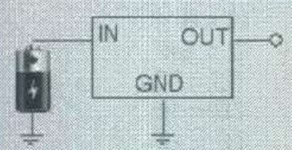
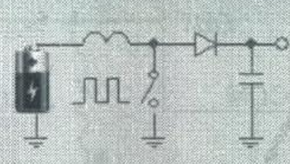
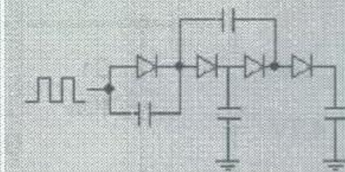
전자 회로 분석 참고 자료

반도체 설계_Buck Booster LDO

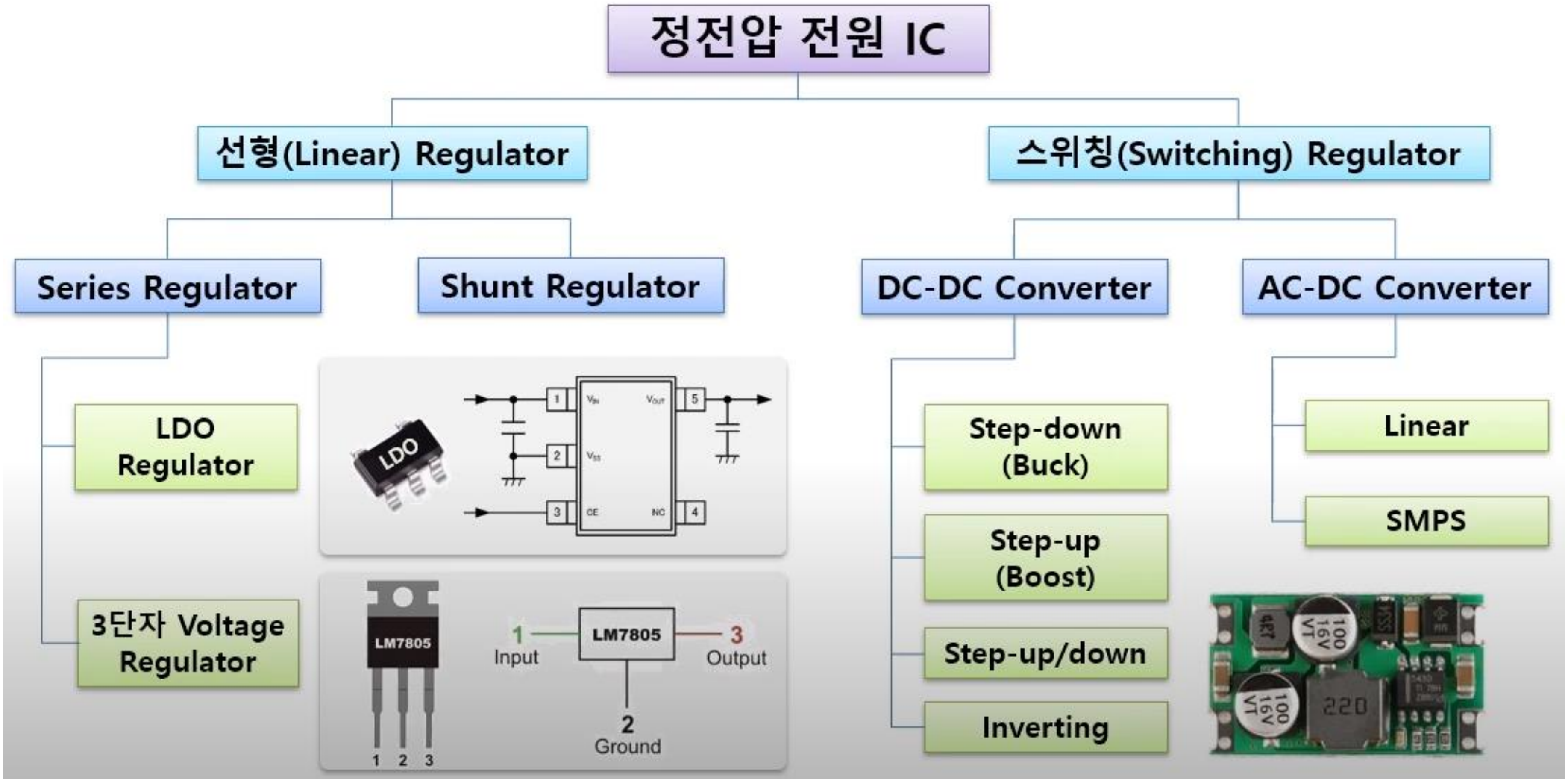
Compare Table of Power Management ICs

Type	LDO	DC-DC	Charge Pump
Architecture			
Operation	Linear	Switching	Switching
Main Component	IC only	Inductor & Diode	Cap. & Diode
Function	Step down only	Step up, Step down Inverter	Step up, Inverter
Power Capacity	Normal	High	Low(<10mA)
Efficiency	Fixed	Good	Good
Thermal Design	---	Advantage	Advantage
Design Complexity	Simple	Complex	Simple
Cost	Advantage		Advantage
Ripple/Noise	Good	Bad	Bad
External Components	Advantage	---	---

- Switching 방식의 전원 System(DC-DC, Charge-Pump)은 Noise가 강하며 반면에 효율은 좋은 편이다.
  Charge Pump는 IC의 내부 전원 Block으로 주로 적용되며 LDO의 경우 입력 전압의 설정이 중요.

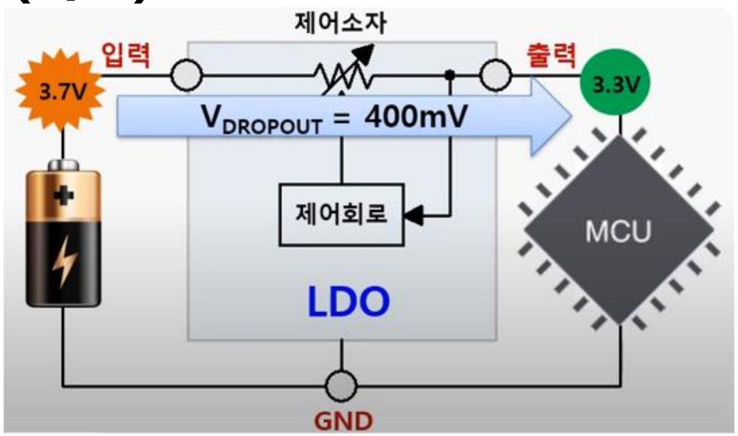
반도체 설계_Buck Booster LDO

LDO(1/7)

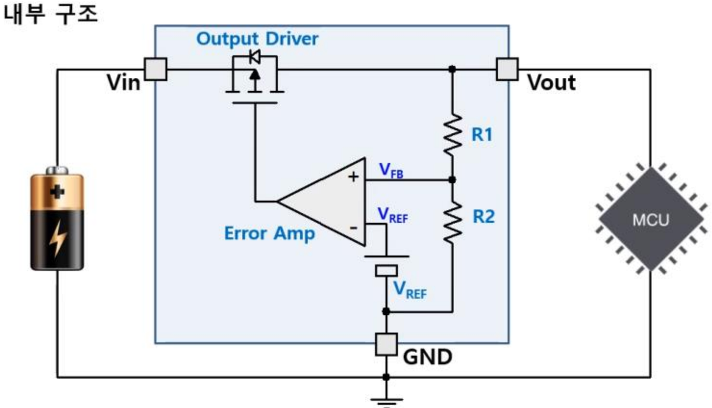


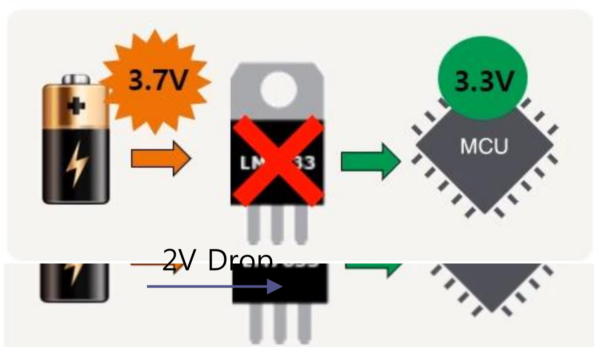
반도체 설계_Buck Booster LDO

LDO(2/7)

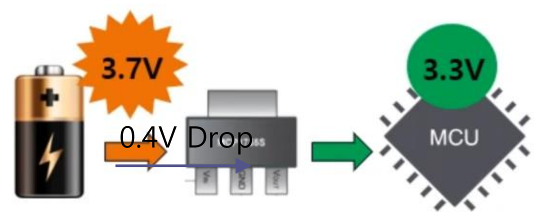


LDO 내부 구조





2V Drop



0.4V Drop

Active 영역 동작

포화 영역 동작

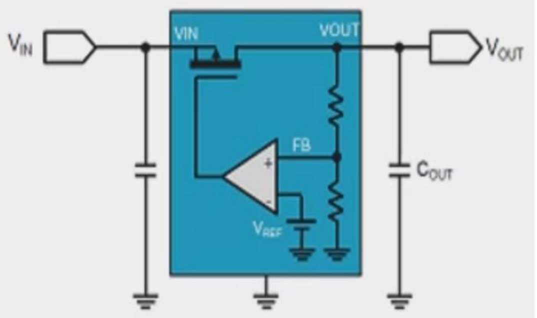
반도체 설계_ LDO → Low Drop Out Voltage Regulator

LDO(3/7)

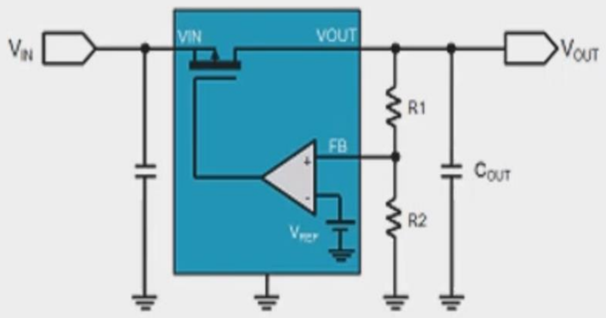
LDO 종류

General Types

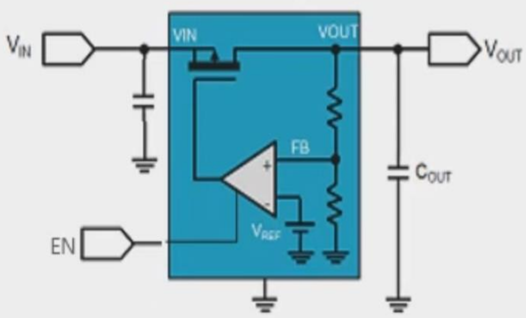
고정 전압형



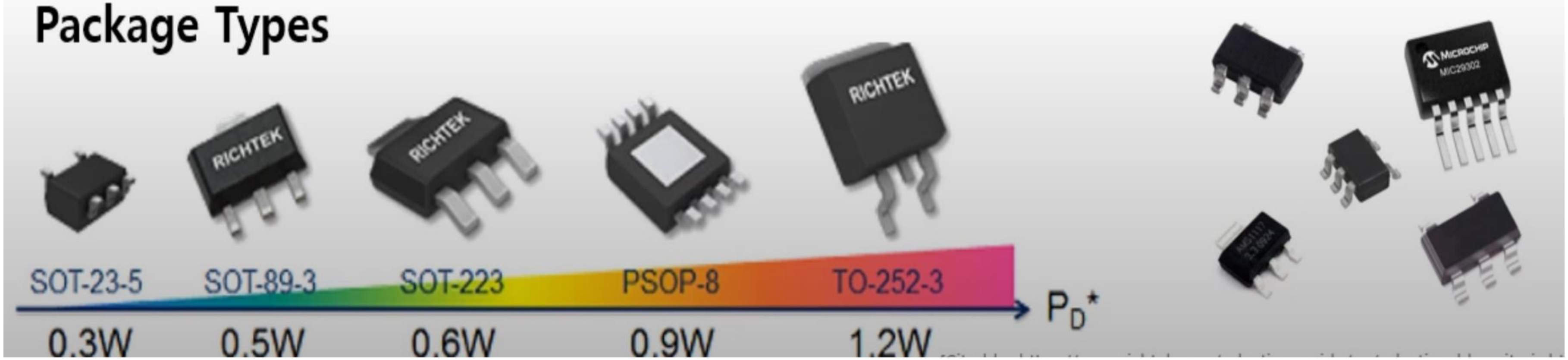
가변 전압형



고정전압/EN 형



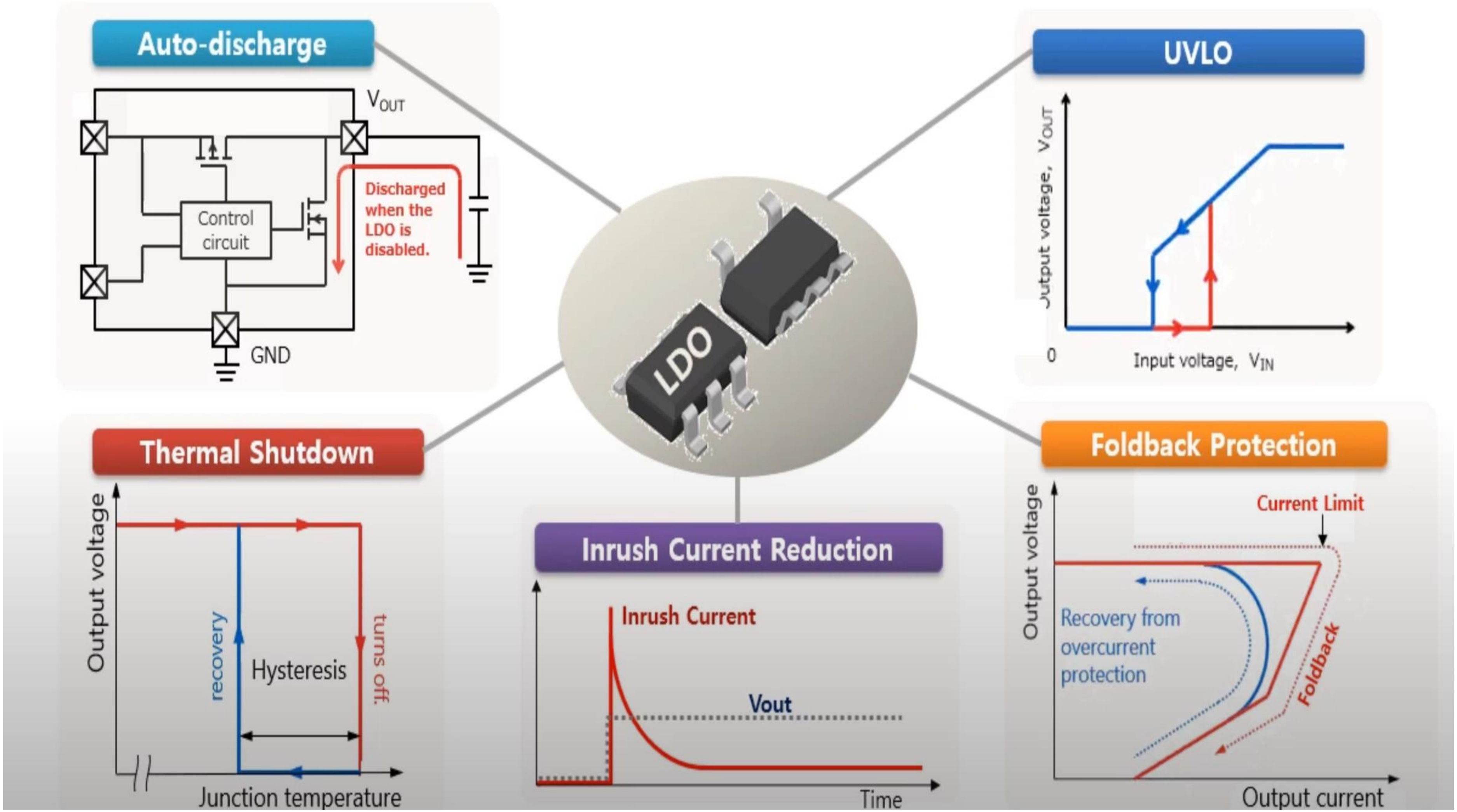
Package Types



반도체 설계_Buck Booster LDO

LDO(4/7)

LDO Protection Functions

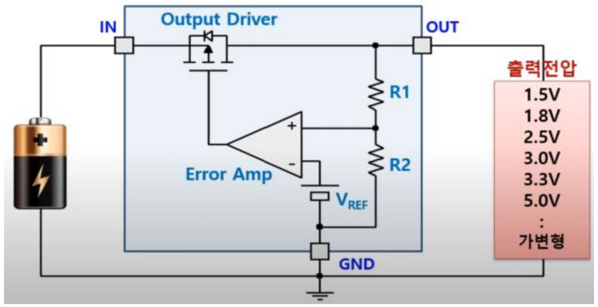


반도체 설계_Buck Booster LDO

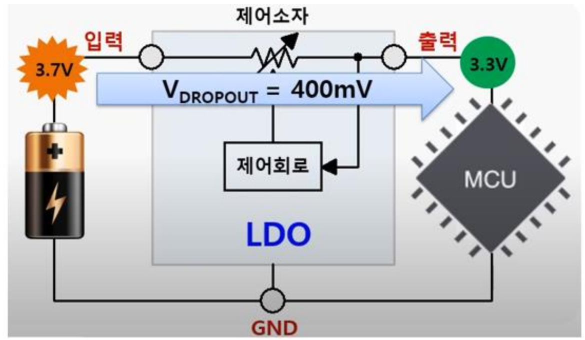
LDO 주요 파라미터

LDO(5/7)

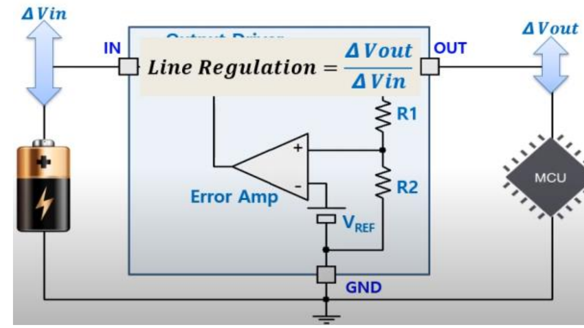
출력 전압



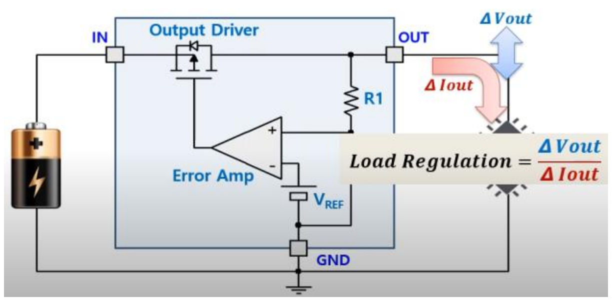
Drop Out Voltage 는 0.5V정도



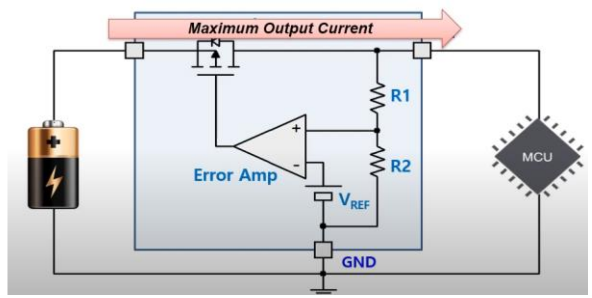
Line Regulation



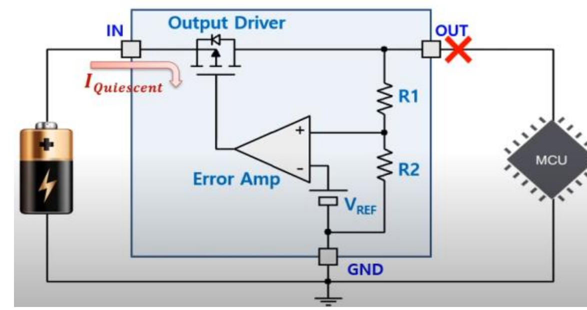
Load Regulation



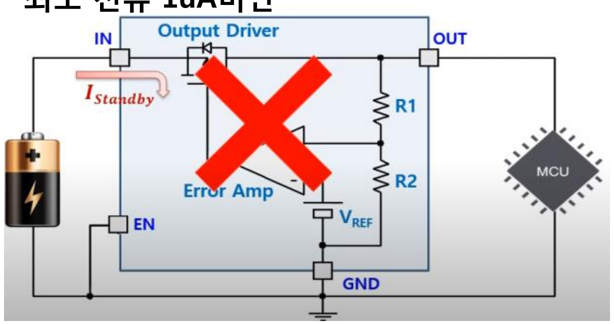
Maximum Output Current



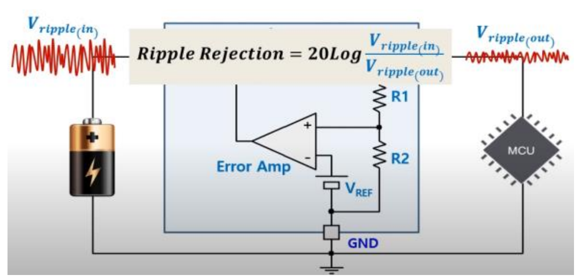
Iquiescent전류는 장상 작동 상태의 무부하
최소 전류 수십 uA미만



Istandby전류는 무작동 상태의
최소 전류 1uA미만



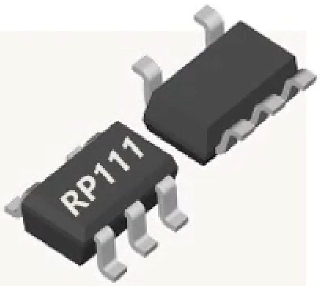
Ripple Rejection



반도체 설계_Buck Booster LDO

LDO(6/7)

LDO 주요 파라미터

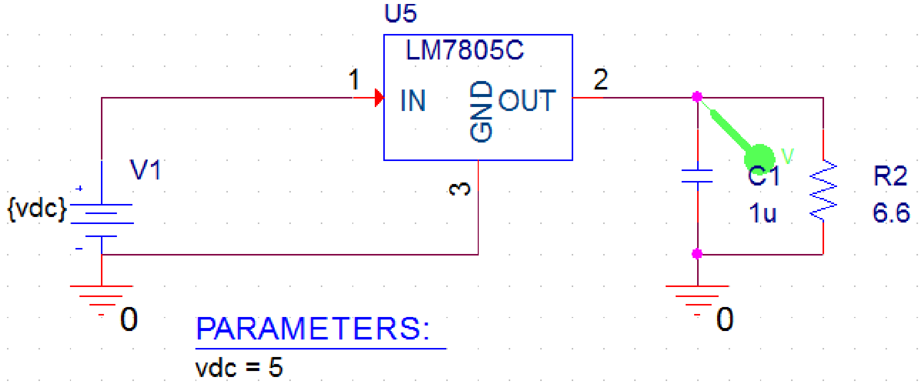


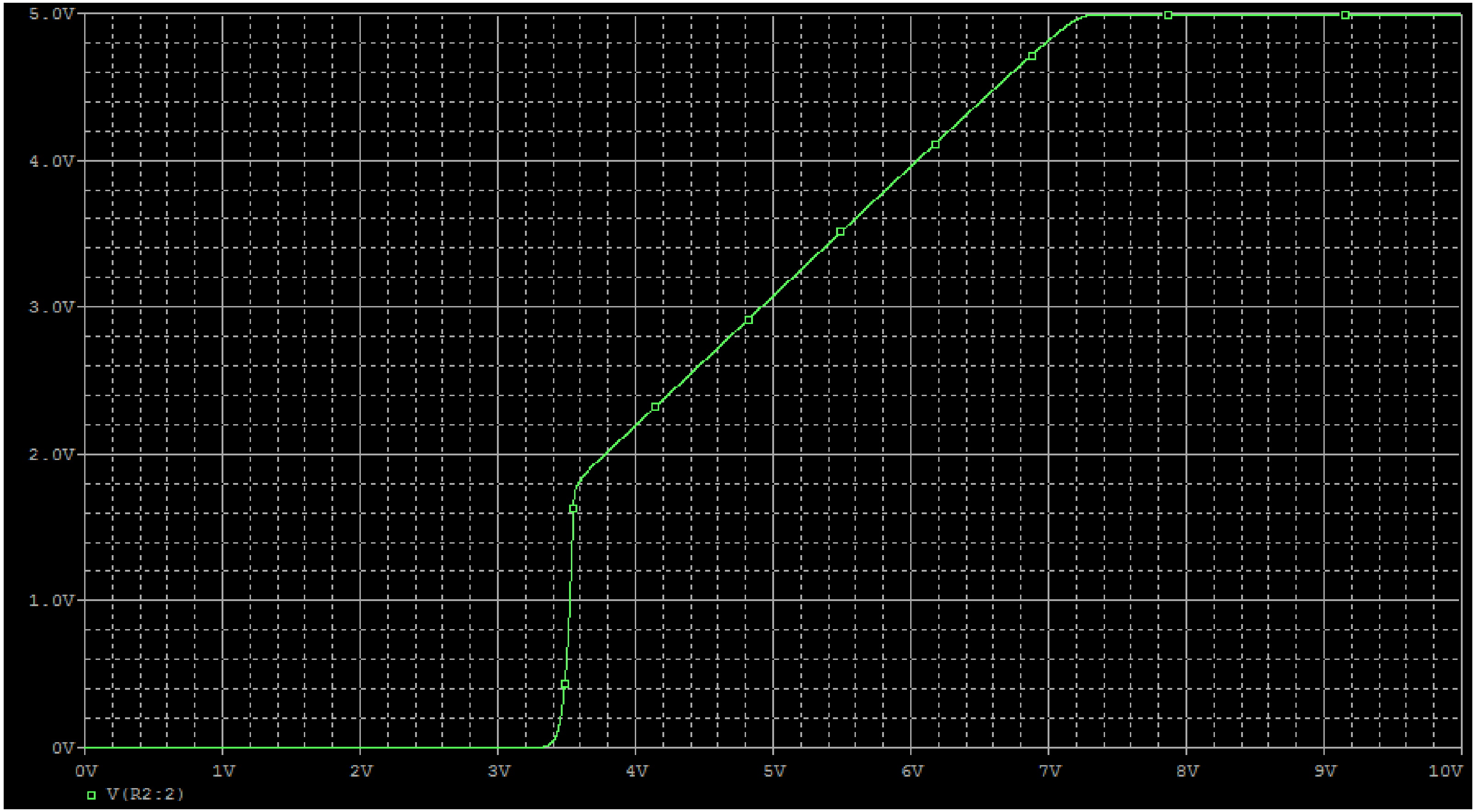
FEATURES

- Input Voltage Range ....1.4V to 5.25V
- Output Voltage Range..0.7V to 3.6V
- Dropout Voltage ....Typ. 0.23V (IOUT=500mA, VOUT=2.5V)
- Output Voltage Accuracy.....................................±0.8% (VOUT ≥1.8V)
- Line Regulation ....Typ. 0.02%/V
- Load Regulation ....Typ. ±50mV(Iout :1mA↔250mA)
- Maximum Output Current ....Typ. 500mA
- Supply Current ....Typ. 80μA
- Standby Current..Typ. 0.1μA
- Ripple Rejection..Typ. 75dB (f=1kHz), 70dB (f=10kHz)
- Output Noise ....Typ. 66 μVrms (10Hz~100kHz)
- Temperature Coefficient ....Typ. ±30ppm/°C (VOUT ≥1.8V)
- Foldback Protection ....Typ. 50mA (Current at short mode)
- Thermal Shutdown Temperature.........................165°C

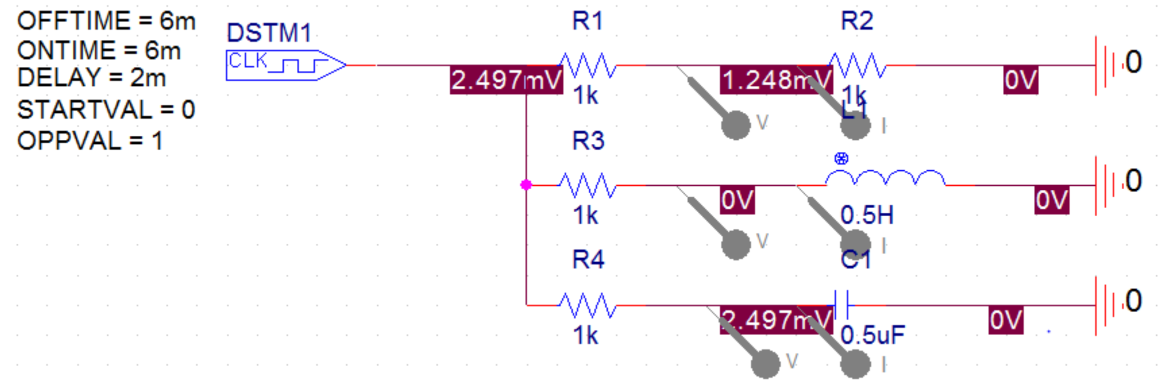
반도체 설계_Buck Booster LDO

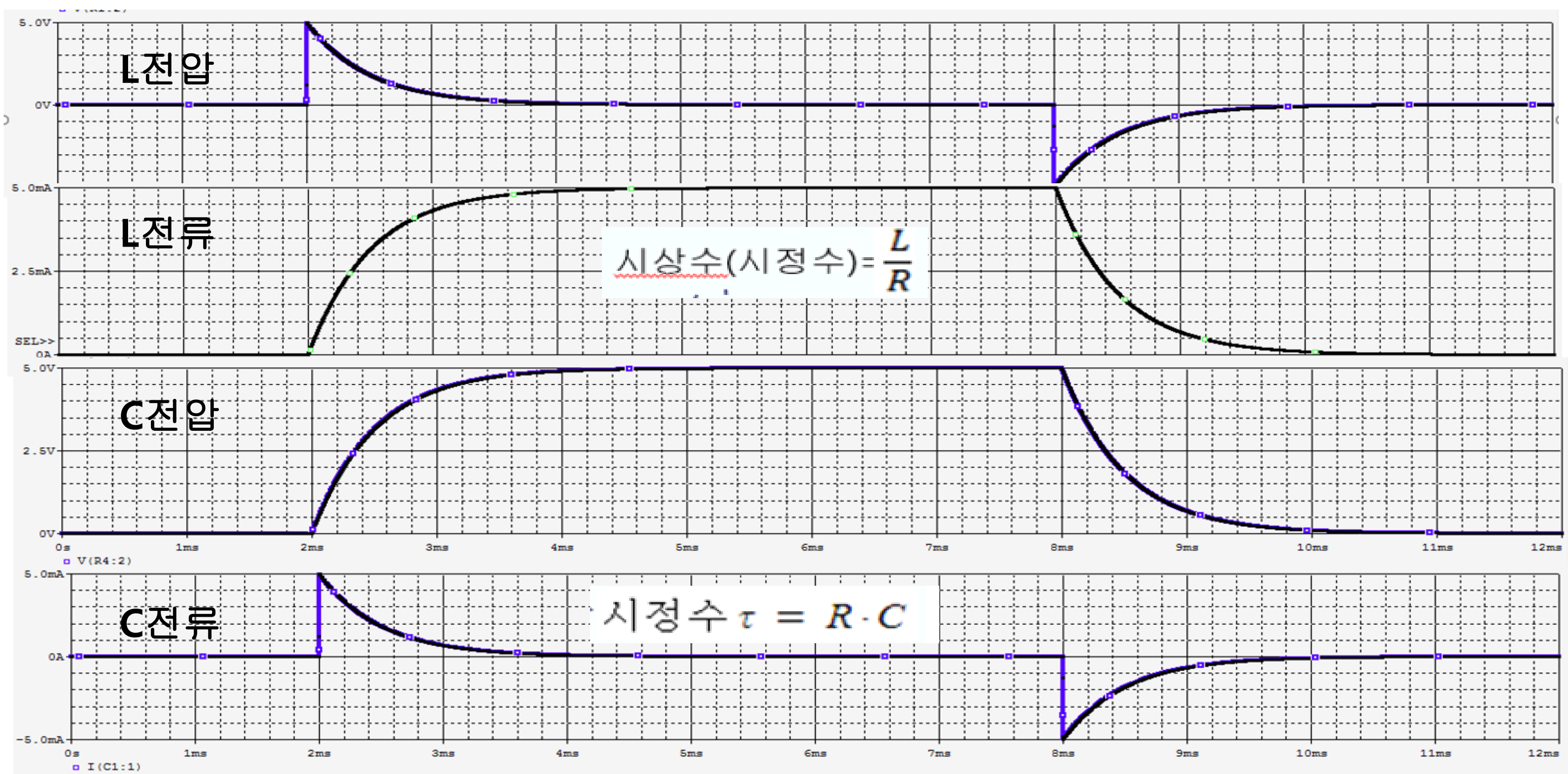
LDO(7/7)





반도체 설계_Buck Booster LDO page100,page323





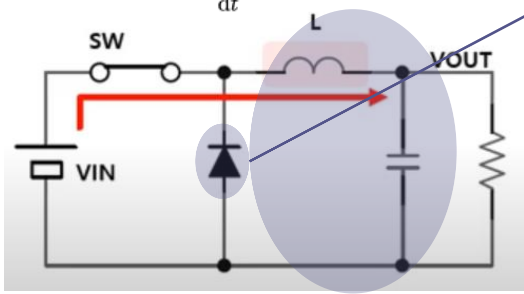
반도체 설계_Buck Booster LDO

https://m.blog.naver.com/techref/222013447041

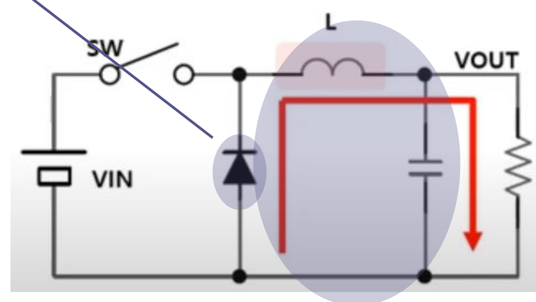
BUCK

$$V_L = L\frac{dI_L}{dt}$$

전류 계산에서 Diode 0.7V는 무시



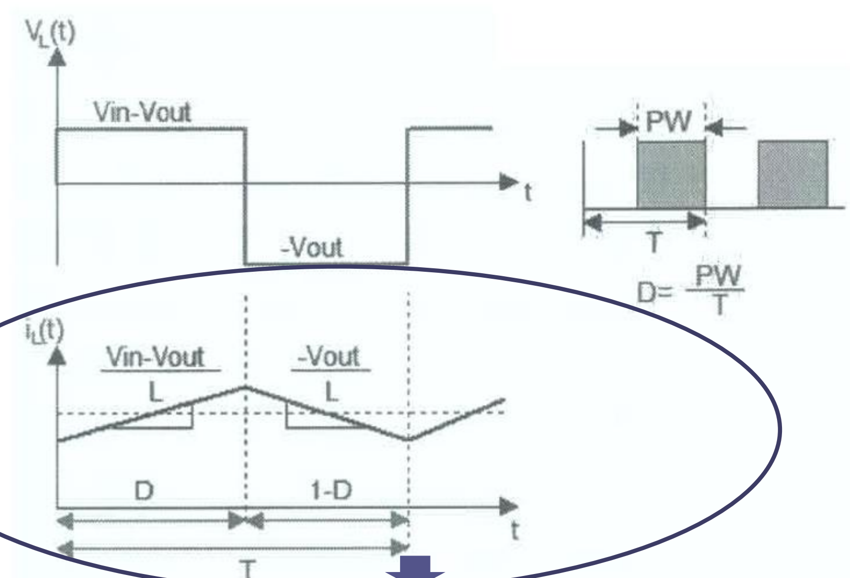
ON 상태 전류



OFF 상태 전류

$$\Delta I_{L_{on}} = \int_0^{t_{on}} \frac{V_L}{L}\,dt = \frac{V_i - V_o}{L} t_{on}, \qquad t_{on} = DT$$

$$\Delta I_{L_{off}} = \int_{t_{on}}^{T=t_{on}+t_{off}} \frac{V_L}{L}\,dt = -\frac{V_o}{L} t_{off}, \qquad t_{off} = (1-D)T$$



T주기 동안 전류 변화량은 **ZERO**

$$\Delta I_{L_{on}} + \Delta I_{L_{off}} = 0 \qquad \frac{V_i - V_o}{L} t_{on} - \frac{V_o}{L} t_{off} = 0$$

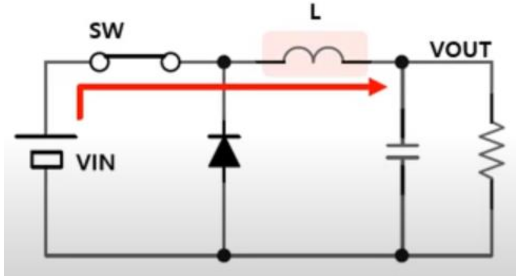
$$(V_i - V_o)\,DT - V_o(1-D)T = 0$$

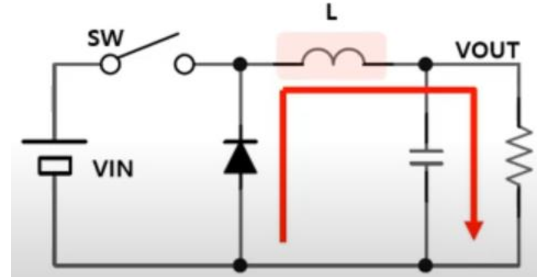
$$DV_i - V_o = 0$$

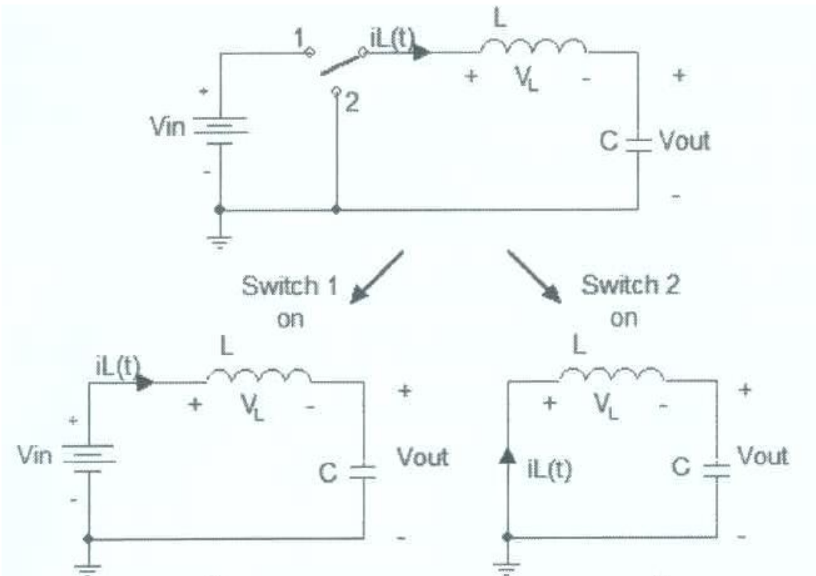
$$\Rightarrow D = \frac{V_o}{V_i}$$

반도체 설계_Buck Booster LDO

Buck





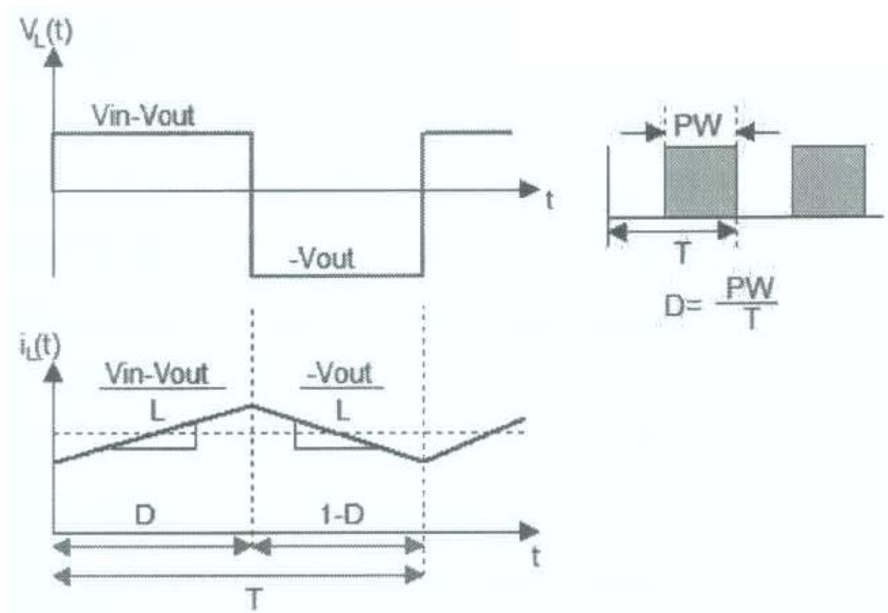


$$V_L = L \cdot \frac{di_L}{dt} = V_{in} - V_{out}$$

$$\frac{di_L}{dt} = \frac{V_{in} - V_{out}}{L}$$

$$V_L = L \cdot \frac{di_L}{dt} = -V_{out}$$

$$\frac{di_L}{dt} = \frac{-V_{out}}{L}$$



$$V_{L\_1-cycle} = (V_{in} - V_{out}) \cdot D + (-V_{out}) \cdot (1 - D)$$

$$= V_{in} \cdot D - V_{out} = 0$$

$$\therefore V_{out} = D \cdot V_{in}$$

$$\Rightarrow D = \frac{V_o}{V_i}$$

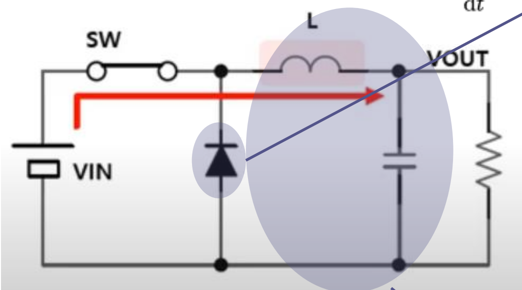
https://www.youtube.com/watch?v=AST2ujrMWas&t=38s
https://gdnn.tistory.com/90

반도체 설계_Buck Booster LDO

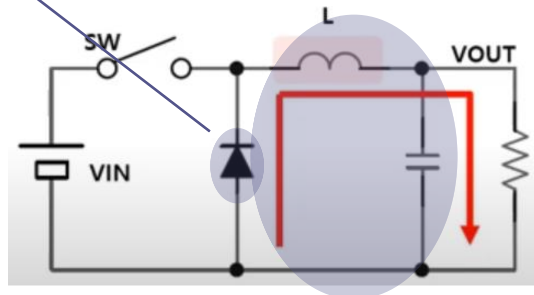
BUCK

$$V_L = L\frac{dI_L}{dt}$$

전류 계산에서 Diode 0.7V는 무시



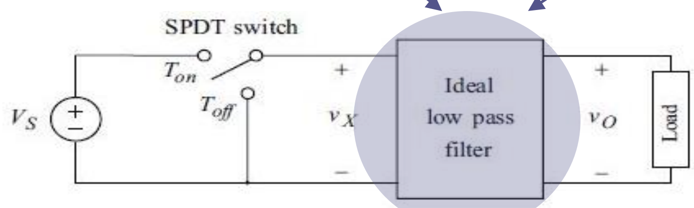
ON 상태 전류



OFF 상태 전류

$$\Delta I_{L_{on}} = \int_0^{t_{on}} \frac{V_L}{L}\,dt = \frac{V_i - V_o}{L} t_{on}, \qquad t_{on} = DT$$

$$\Delta I_{L_{off}} = \int_{t_{on}}^{T=t_{on}+t_{off}} \frac{V_L}{L}\,dt = -\frac{V_o}{L} t_{off}, \qquad t_{off} = (1-D)T$$

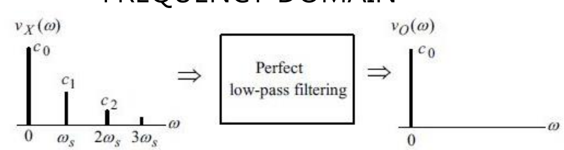


Low Pass Filter

TIME DOMAIN

Low Pass Filter후 시간T 평균값

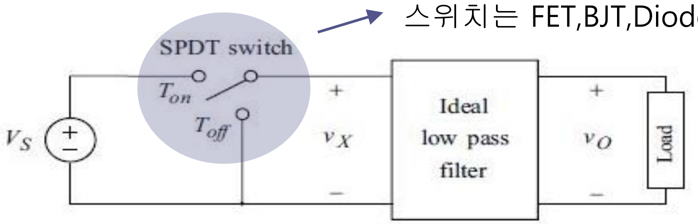
FREQUENCY DOMAIN



Low Pass Filter후 DC성분만 통과

$$\Rightarrow D = \frac{V_o}{V_i}$$

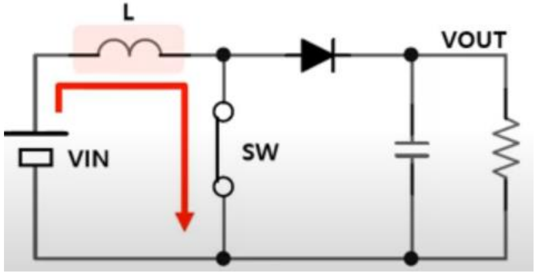
스위치는 FET,BJT,Diode등으로 구현

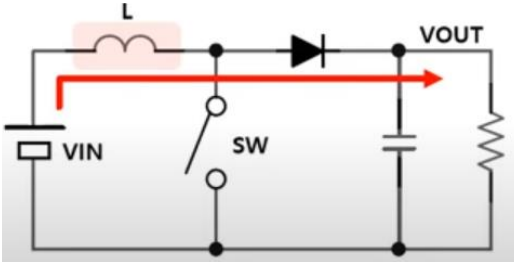


https://m.blog.naver.com/techref/222013447041

반도체 설계_Buck Booster LDO

Booster





$$\Delta I_{L_{\mathrm{On}}} = \frac{1}{L}\int_0^{DT} V_i\,dt = \frac{DT}{L}V_i$$

$$V_i - V_o = L\frac{dI_L}{dt}$$

$$\Delta I_{L_{\mathrm{Off}}} = \int_{DT}^{T} \frac{(V_i - V_o)\,dt}{L} = \frac{(V_i - V_o)(1-D)T}{L}$$

$$\Delta I_{L_{\mathrm{On}}} + \Delta I_{L_{\mathrm{Off}}} = \frac{V_i DT}{L} + \frac{(V_i - V_o)(1-D)T}{L} = 0$$

$$\frac{V_o}{V_i} = \frac{1}{1-D}$$

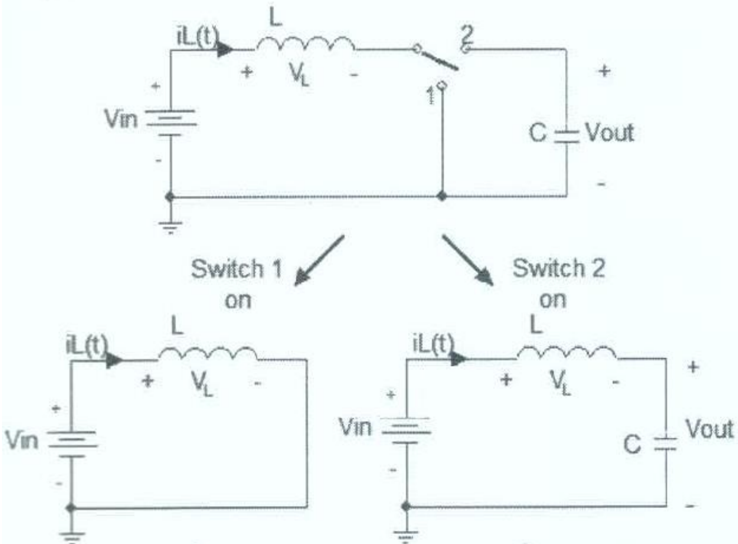
https://www.youtube.com/watch?v=AST2ujrMWas&t=38s
https://gdnn.tistory.com/90

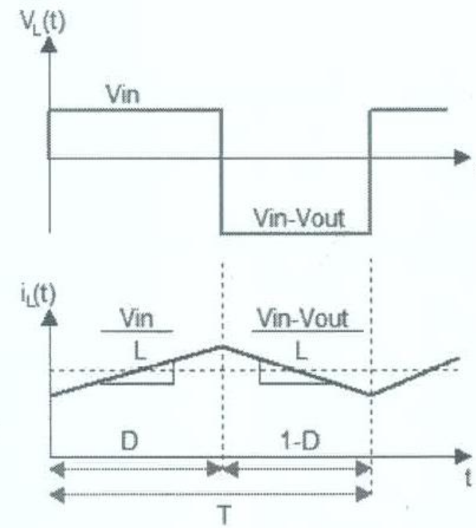
반도체 설계_Buck Booster LDO

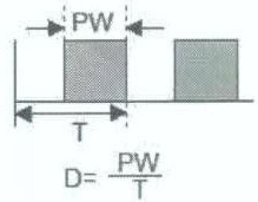
Booster

DC−DC Boost Converter Inductor Voltage & Current

$$V_{out} = \frac{V_{in}}{1-D}$$







$$V_L = L\cdot\frac{di_L}{dt} = V_{in}$$

$$\frac{di_L}{dt} = \frac{V_{in}}{L}$$

$$V_L = L\cdot\frac{di_L}{dt} = V_{in} - V_{out}$$

$$\frac{di_L}{dt} = \frac{V_{in}-V_{out}}{L}$$

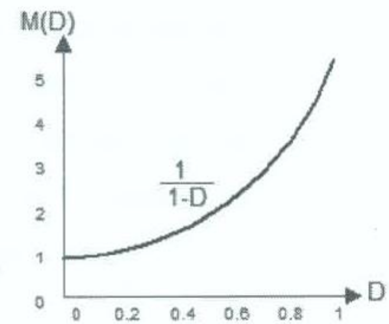
$$V_{L\_1-cycle} = (V_{in})\cdot D + (V_{in} - V_{out})\cdot(1-D)$$

$$= V_{in}\cdot D + V_{in} - V_{in}\cdot D - V_{out} + V_{out}\cdot D = 0$$

$$V_{in} = V_{out}(1-D)$$

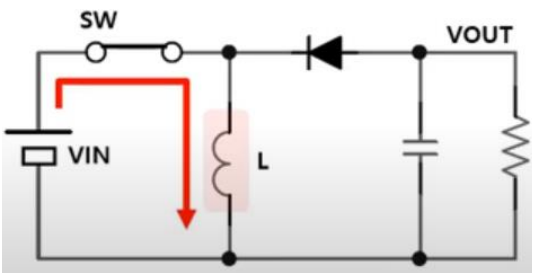
$$\therefore V_{out} = \frac{V_{in}}{1-D}$$

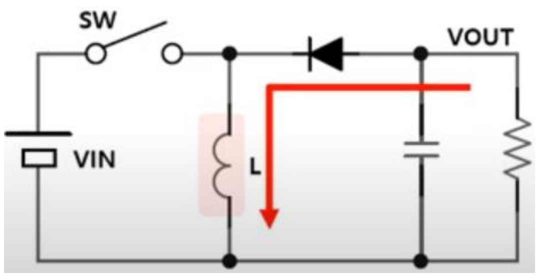
- 인덕터 전압과 전류 관계식에 의해 SW의 On(D구간)과 Off(1-D구간) 영역에서의 인덕터 전압과 전류 값이 결정되며 Converter의 전압과 전류 특성을 파악할 수 있다.
- 인덕터 전압(V_L)은 Steady State 영역에서 한 주기 단위에서 평균이 0V이므로 전압 변환 비율 M(D)=1/(1-D)로 선형적으로 1 이상의 범위에서 지수함수적 증가



반도체 설계_Buck Booster LDO

Buck-Booster





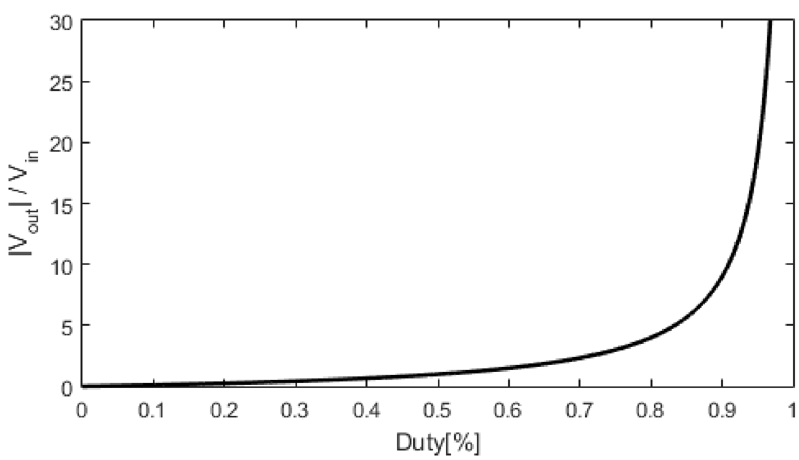
$$\Delta I_{L_{On}} = \int_0^{DT} \mathrm{d}\,I_L = \int_0^{DT} \frac{V_i}{L}\,\mathrm{d}\,t = \frac{V_i\,DT}{L}$$

$$\Delta I_{L_{Off}} = \int_0^{(1-D)T} \mathrm{d}\,I_L = \int_0^{(1-D)T} \frac{V_o\,\mathrm{d}\,t}{L} = \frac{V_o\,(1-D)\,T}{L}$$

$$\Delta I_{L_{On}} + \Delta I_{L_{Off}} = \frac{V_i\,DT}{L} + \frac{V_o\,(1-D)\,T}{L} = 0$$

$$\frac{V_o}{V_i} = -\frac{D}{1-D}$$

$$\frac{V_o}{V_i} = -\frac{D}{1-D}$$



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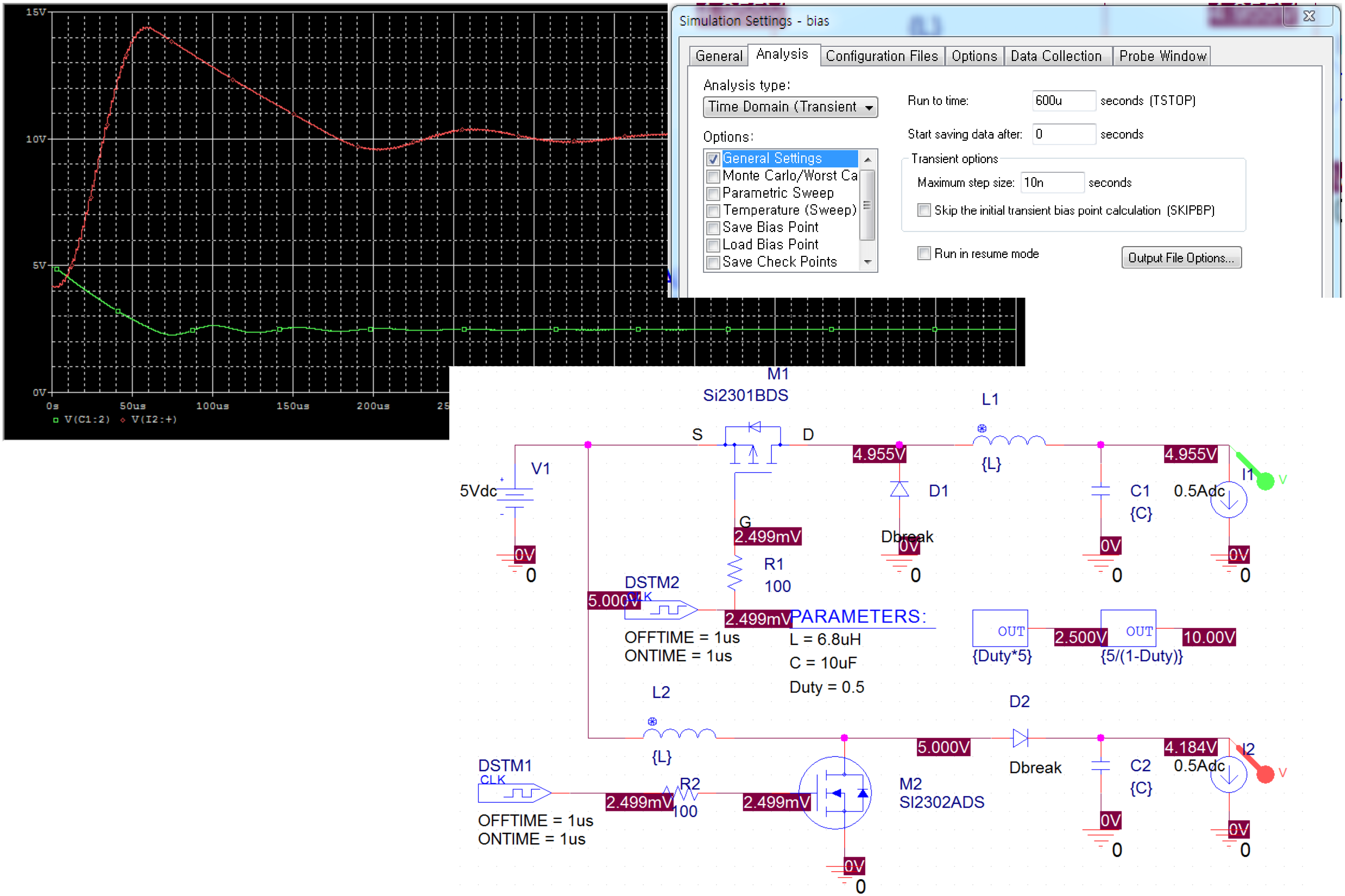

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