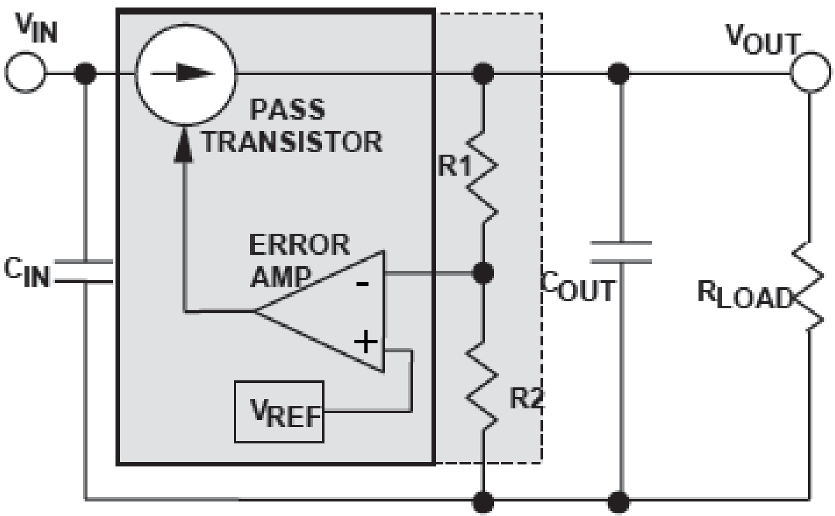
线性稳压器 基础知识

什么是线性稳压器（Linear Regulator）

- 线性稳压器通过一个通流器件（通常为晶体管或MOSFET）承受不需要的电压，从而使输入电压保持恒定。
- 通流器件的特性类似于一个可调电阻。

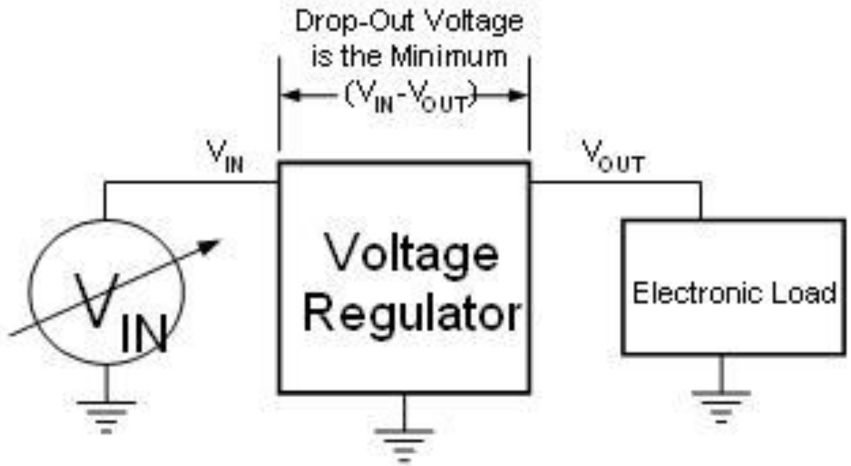


线性稳压器的优缺点

优点	缺点
• 低输出纹波，低噪声，EMI辐射小 • 成本低（在小功率时） • 结构简单，只需少数几个外围元件，容易调试和设计 • 暂态响应快 • 短路保护容易设计	• 效率低，能量以热能的形式消耗，当 V_{in} 和 V_{out} 相差较大时尤为突出 • 散热要求高，功率越大，或V_{in} 和 V_{out} 相差越大，线性稳压器产生的热损耗越大 • 只能降压

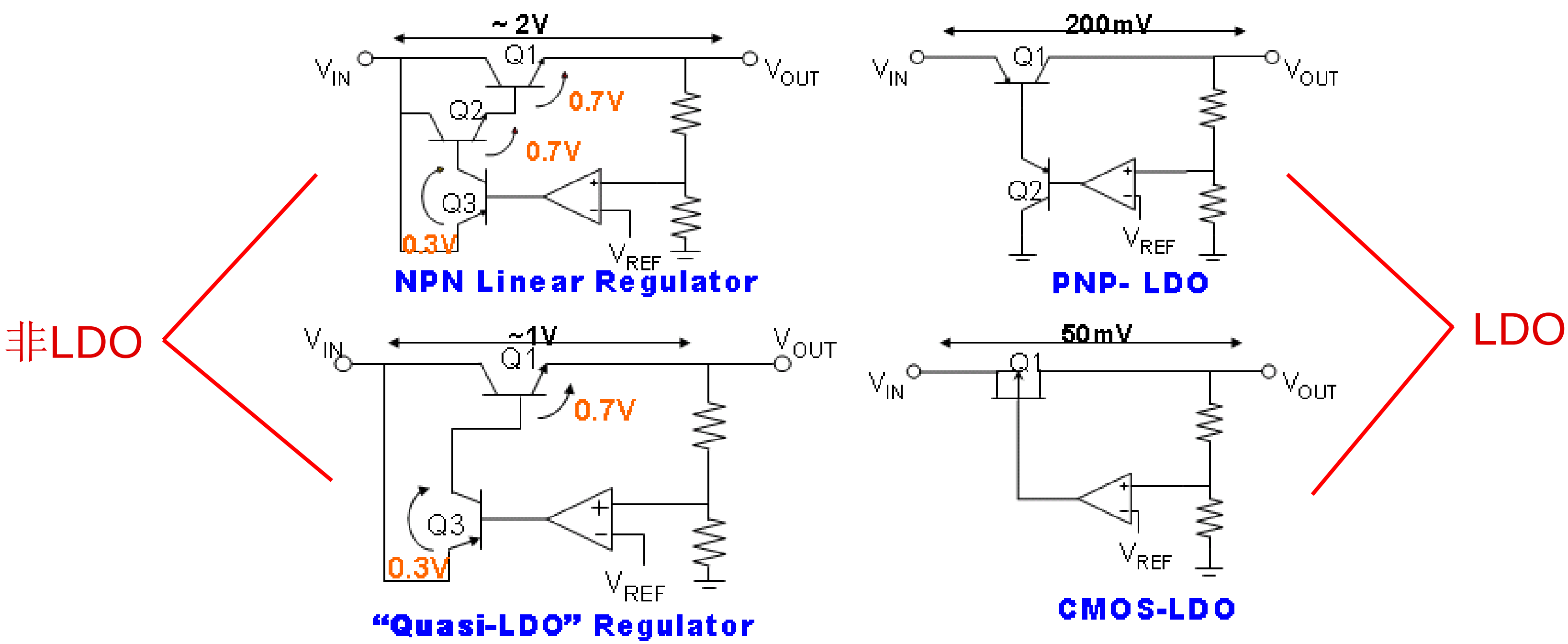
线性稳压器的最小压差 (dropout voltage)

- 线性稳压器为了维持正常工作，V_{in} 和 V_{out} 之间必须有一个差值，此差值的最小值称为线性稳压器的最小压差 (dropout voltage)



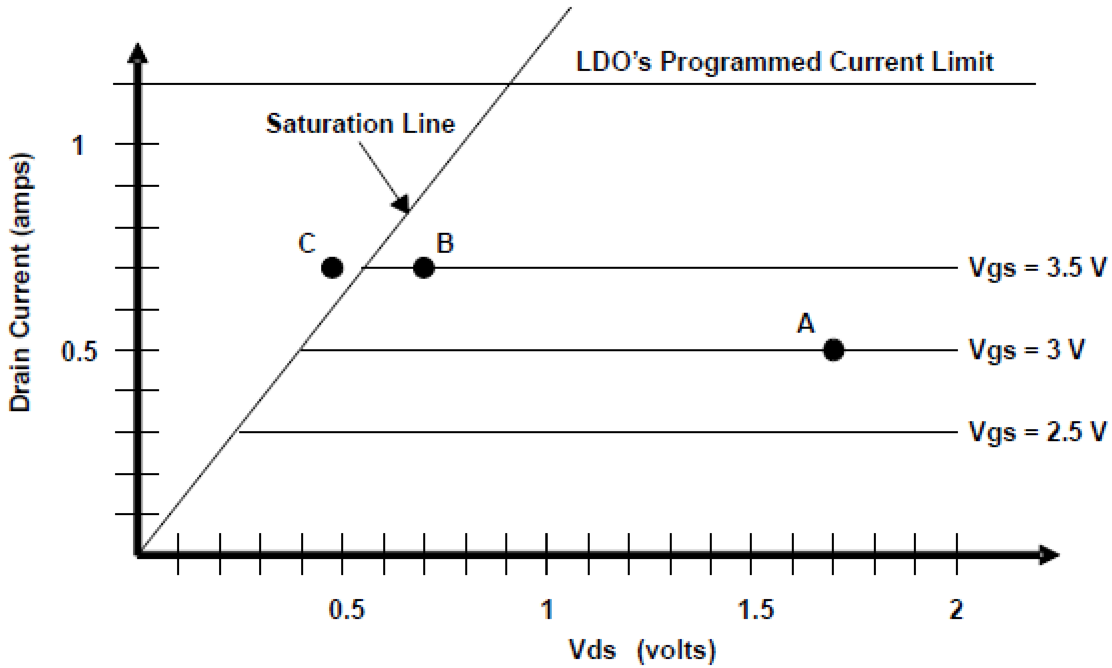
线性稳压器的类型

- 线性稳压器的通流器件可以是晶体管或者MOSFET，不同的通流器件有不同的最小压差特性。
  - NPN型：最小压差较大，一般在2V以上。如7805，LM317。
  - “准LDO”型：最小压差比NPN型小，但仍在1V以上。如LM1117。
  - PNP型：最小压差较小，但对输出电容ESR有要求。如TPS7A4901。
  - MOSFET型：最小压差很小，PMOS型对输出电容ESR有要求。如TPS7A8300。
- 最小压差很小的线性稳压器称为LDO(low drop-out linear regulator)



理解Dropout

- 为维持输出电流，线性稳压器必须工作在线性区。当VDS下降到一定程度时，线性稳压器会进入饱和区，导致电流下降。
- 例如Vin=5V, Vout=3.3V, Iout=500mA时，线性稳压器工作在A点。若输入电压持续下降，会导致FET饱和，线性区与饱和区的临界点就是dropout电压。



抢答: TPS7A4901的Dropout Voltage?

V_{DO}	Dropout voltage	V_{IN} = 95% $V_{OUT(nom)}$, I_{OUT} = 100 mA	260		mV
		V_{IN} = 95% $V_{OUT(nom)}$, I_{OUT} = 150 mA	333	600	mV

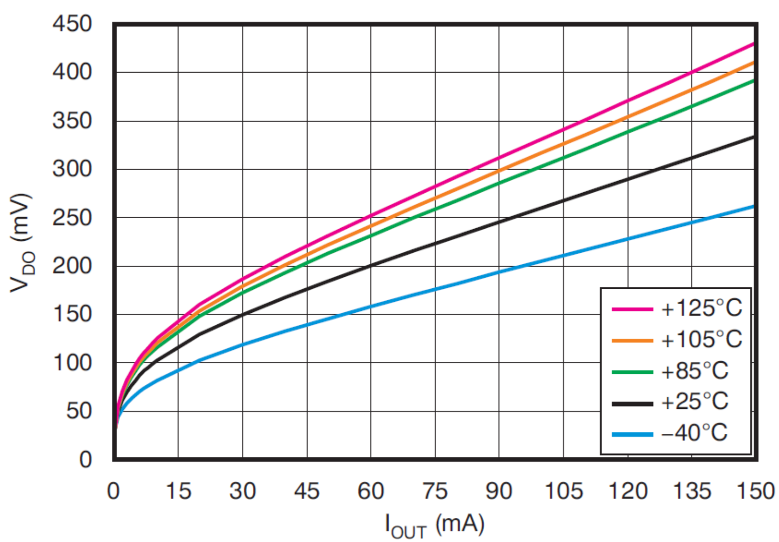


Figure 9. Dropout Voltage vs Output Current

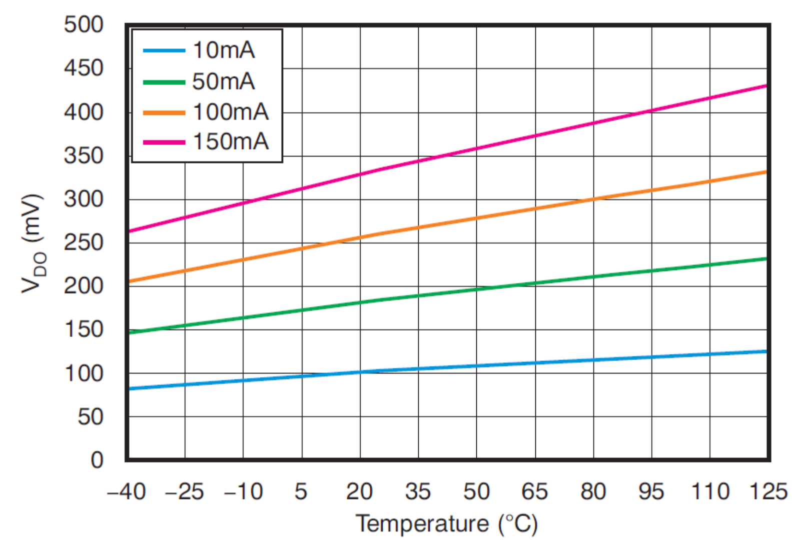
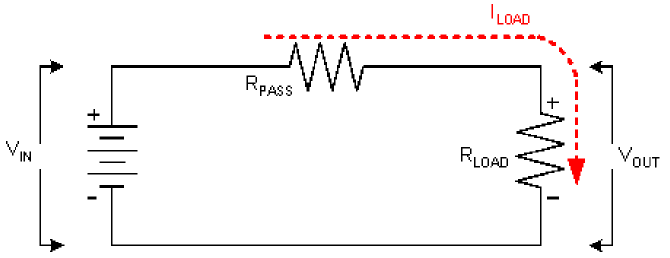


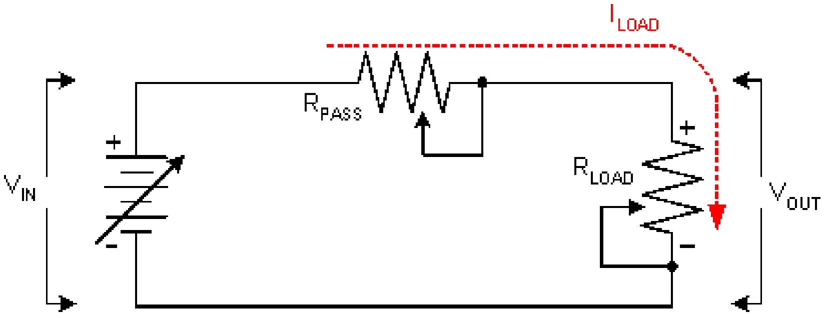
Figure 10. Dropout Voltage vs Temperature

线性稳压器的简化模型(Simple Model)

- A basic (first order) linear voltage regulator can be modeled with two resistors and a power supply for V_{IN}.

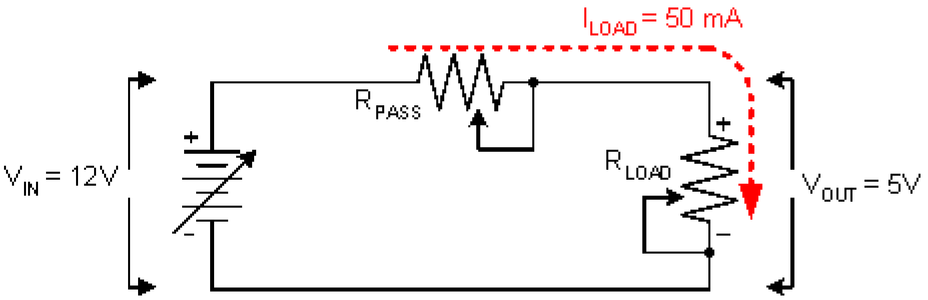


- In reality, the only constant is the output voltage, V_{OUT}. Everything else can, and will, be constantly changing.
- The input voltage may have changes due to outside influences, the load current may change due to a dynamic change in the behavior of the load.
- Changes in these variables can all happen simultaneously, and the value needed for R_{PASS} to hold V_{OUT} at a constant value will need to change as well.



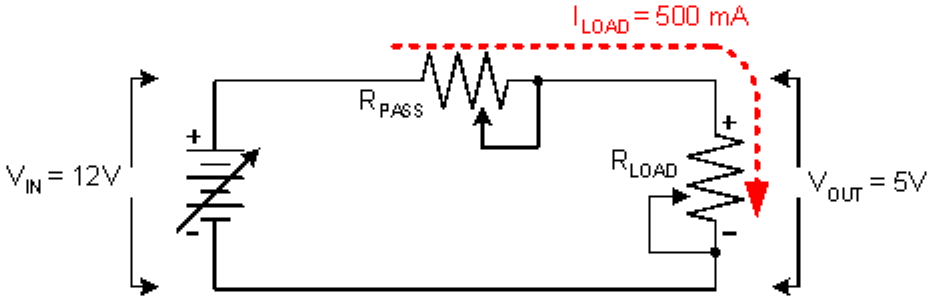
Simple Model with Values

- For the first example, we will assign typical operating values and calculate the value needed for the series pass element R_{PASS}.
  - V_{IN} = 12V
  - V_{OUT}= 5V
  - I_{LOAD} = 50 mA
- With V_{IN} = 12V and V_{OUT} = 5V, the voltage across R_{PASS} = (12V - 5V) = 7V
- With the current through R_{PASS} = I_{LOAD} = 50 mA, the needed resistance for R_{PASS} = (7V / 50mA)= 140 Ohms



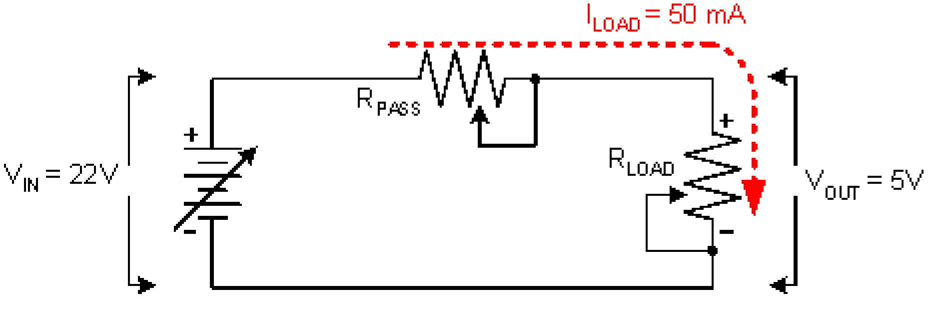
Simple Model with Change of Load Current

- For the second example, we will change the load current from 50mA to 500mA and calculate the value needed for the series pass element R_{PASS}.
  - V_{IN} = 12V
  - V_{OUT} = 5V
  - I_{LOAD} = 500 mA
- With V_{IN} = 12V and V_{OUT} = 5V, the voltage across R_{PASS} = (12V - 5V) = 7V
- With the current through R_{PASS} = I_{LOAD} = 500 mA, the needed resistance for R_{PASS} = (7V / 500mA)= 14 Ohms



Simple Model with Change in Input Voltage

- For the third example, we will change the input voltage from 12V to 22V and calculate the value needed for the series pass element R_{PASS}.
  - V_{IN} = 22V
  - V_{OUT} = 5V
  - I_{LOAD} = 50 mA
- With V_{IN} = 22V and V_{OUT} = 5V, the voltage across R_{PASS} = (22V - 5V) = 17V
- With the current through R_{PASS} = I_{LOAD} = 50 mA, the needed resistance for R_{PASS} = (17V / 50mA) = 340 Ohms



The Control Loop

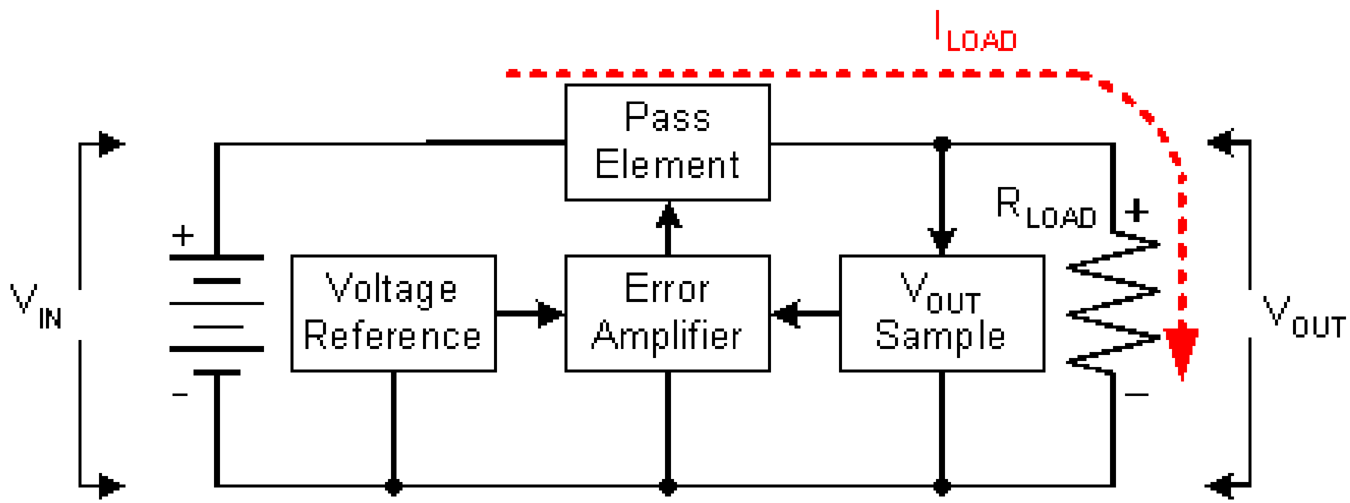
- It has been shown that the resistance of series pass element, R_{PASS}, needs to change as the operating conditions change.
- This is accomplished with a control loop.
- The error amplifier monitors the sampled output voltage, compares it to a known reference voltage, and actively changes R_{PASS} to keep V_{OUT} constant.
  - A characteristic of any linear voltage regulator is that it requires a finite amount of time to "correct" the output voltage after a change in load current demand.
  - This "time lag" defines the characteristic called transient response, which is a measure of how fast the regulator returns to steady-state conditions after a load change

暂态响应

Simple Model, with Control Loop Blocks

- Here 'simple' blocks have added to show the four basic divisions of any linear voltage regulator:

  1) Series Pass Element
  2) Error Amplifier
  3) VOUT Sampling Network
  4) Reference Voltage



线性稳压器的其他关键性能指标

- 静态电流(Quiescent current)：空载时线性稳压器消耗的电流。
  - 静态电流是考察线性稳压器是否低功耗的重要指标，在电池供电的应用中尤为关键。
- 电源抑制比(Power supply rejection ratio, 简称PSRR)：输出电压纹波和输入电压纹波的比值。
  - PSRR是考察线性稳压器抗噪性能的关键指标，在对噪声要求较高的应用如音频，RF和无线中需要重点关注。
- 宽带噪声(Broadband noise)：规定频率范围的噪声总和。
  - 对于噪声要求较高的应用，如PLL, RF和无线等，需要重点注意。