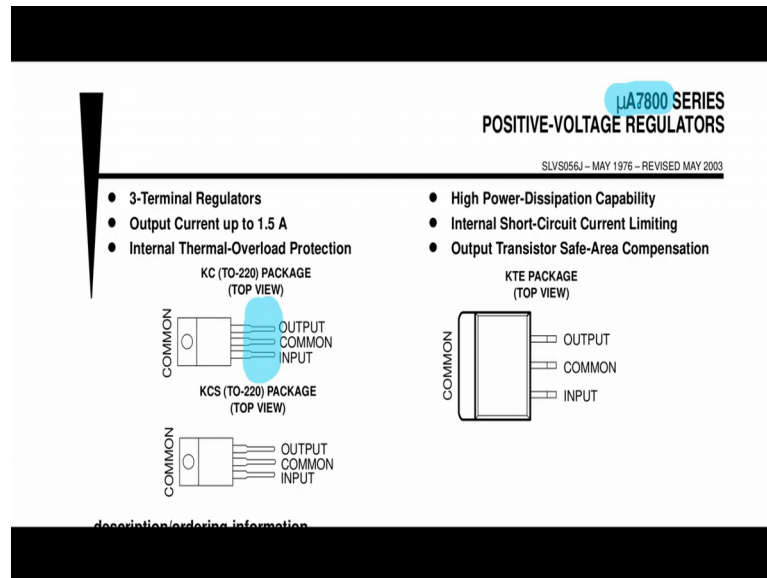


Fundamentals of Power Electronics
Prof. L. Umanand
Department of Electronics Systems Engineering
Indian Institute of Science, Bengaluru

Lecture – 42
Datasheet of few IC regulators

(Refer Slide Time: 00:27)



Let us look at some commercial linear regulators. The mu A78 series regulator is a very popular and commonly available linear regulator. It is a 3-pin you see here 3-pin, 3-terminal linear regulator. You have a input the output and the common pin very popular, and it comes in various fixed outputs 78xx or 00 series. If you get 7805, it is a 5 volt regulator. If it is 7808, it is a 8 volt regulator; 7810 7812, 12 volt; 7815, 15 volt regulator so on.

(Refer Slide Time: 01:17)

POSITIVE-VOLTAGE REGULATORS

SLVS056J – MAY 1976 – REVISED MAY 2003

- 3-Terminal Regulators
- Output Current up to 1.5 A
- Internal Thermal-Overload Protection
- High Power-Dissipation Capability
- Internal Short-Circuit Current Limiting
- Output Transistor Safe-Area Compensation

KC (TO-220) PACKAGE (TOP VIEW)

KCS (TO-220) PACKAGE (TOP VIEW)

KTE PACKAGE (TOP VIEW)

description/ordering information

This series of fixed-voltage integrated-circuit voltage regulators is designed for a wide range of applications.

Very popular output currents up to 1.5 amps, and it is available in TO-220 package.

(Refer Slide Time: 01:27)

ORDERING INFORMATION

T_J	V_O (NOM) (V)	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING
0°C to 125°C	5	POWER-FLEX (KTE)	Reel of 2000	μ A7805CKTER	μ A7805C
		TO-220 (KC)	Tube of 50	μ A7805CKC	μ A7805C
		TO-220, short shoulder (KCS)	Tube of 20	μ A7805CKCS	μ A7805C
	8	POWER-FLEX (KTE)	Reel of 2000	μ A7808CKTER	μ A7808C
		TO-220 (KC)	Tube of 50	μ A7808CKC	μ A7808C
		TO-220, short shoulder (KCS)	Tube of 20	μ A7808CKCS	μ A7808C
	10	POWER-FLEX (KTE)	Reel of 2000	μ A7810CKTER	μ A7810C
		TO-220 (KC)	Tube of 50	μ A7810CKC	μ A7810C
		POWER-FLEX (KTE)	Reel of 2000	μ A7812CKTER	μ A7812C
	12	TO-220 (KC)	Tube of 50	μ A7812CKC	μ A7812C
		TO-220, short shoulder (KCS)	Tube of 20	μ A7812CKCS	μ A7812C
		POWER-FLEX (KTE)	Reel of 2000	μ A7815CKTER	μ A7815C
15	TO-220 (KC)	Tube of 50	μ A7815CKC	μ A7815C	
	TO-220, short shoulder (KCS)	Tube of 20	μ A7815CKCS	μ A7815C	
	POWER-FLEX (KTE)	Reel of 2000	μ A7824CKTER	μ A7824C	
24	TO-220 (KC)	Tube of 50	μ A7824CKC	μ A7824C	

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at [www.ti.com](#).

See here different 78x x series this is a five volt regulator this a 8 volt regulator, a 12 volt regulator, it is the 15 volt regulator, 24 volt regulator so on. So, these are constant voltage regulators just 3-terminals, you put this 3-terminals no other extra components and you are in business.

(Refer Slide Time: 01:50)

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

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

In the data sheet of the 78xx series you will see some of the input important parameters output voltage minimum 4.8 to 5.2. Now, the input voltage regulation ok, so for a variation from 7 to 25 volts, 3 to 100, you should map it into the regulation coefficient that we just now discussed. Ripple rejection, output voltage regulation that is with respect to the load. There is a temperature coefficient of output voltage with respect to variation in temperature ok.

(Refer Slide Time: 02:30)

Ripple rejection	$V_I = 8\text{ V to }12\text{ V}$		1	50		
	$V_I = 8\text{ V to }18\text{ V}$, $f = 120\text{ Hz}$	0°C to 125°C	62	78	dB	
Output voltage regulation	$I_O = 5\text{ mA to }1.5\text{ A}$	25°C	15			100
	$I_O = 250\text{ mA to }750\text{ mA}$		5			
Output resistance	$f = 1\text{ kHz}$	0°C to 125°C	0.017			Ω
Temperature coefficient of output voltage	$I_O = 5\text{ mA}$	0°C to 125°C	-1.1			mV/°C
Output noise voltage	$f = 10\text{ Hz to }100\text{ kHz}$	25°C	40			μV
Dropout voltage	$I_O = 1\text{ A}$	25°C	2			V
Bias current		25°C	4.2	8		mA
Bias current change	$V_I = 7\text{ V to }25\text{ V}$	0°C to 125°C	1.3			mA
	$I_O = 5\text{ mA to }1\text{ A}$		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.

These are the regulation coefficients that would matter, and you will have to use these in effectively designing your regulators.

(Refer Slide Time: 02:40)

μA723

PRECISION VOLTAGE REGULATORS

SLVS057D – AUGUST 1972 – REVISED JULY 1999

- 150-mA Load Current Without External Power Transistor
- Adjustable Current-Limiting Capability
- Input Voltages up to 40 V
- Output Adjustable From 2 V to 37 V
- Direct Replacement for Fairchild μA723C

description

The μA723 is a precision integrated-circuit voltage regulator, featuring high ripple rejection, excellent input and load regulation, excellent temperature stability, and low standby current. The circuit consists of a temperature-compensated reference-voltage amplifier, an error amplifier, a 150-mA output transistor, and an adjustable-output current limiter.

The μA723 is designed for use in positive or negative power supplies as a series, shunt, switching, or floating regulator. For output currents exceeding 150 mA, additional pass elements can be connected as shown in

D OR N PACKAGE (TOP VIEW)

NC	1	14	NC
CURR LIM	2	13	FREQ COMP
CURR SENS	3	12	VCC+
IN-	4	11	VC
IN+	5	10	OUTPUT
REF	6	9	VZ
VCC-	7	8	NC

Another versatile precision regulator available in the market is the 7803.7 Another versatile precision regulator available in the market is the muA723. It comes in a d package and few other packages as well.

(Refer Slide Time: 03:07)

SLVS057D – AUGUST 1972 – REVISED JULY 1999

- 150-mA Load Current Without External Power Transistor
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description

The μA723 is a precision integrated-circuit voltage regulator, featuring high ripple rejection, excellent input and load regulation, excellent temperature stability, and low standby current. The circuit consists of a temperature-compensated reference-voltage amplifier, an error amplifier, a 150-mA output transistor, and an adjustable-output current limiter.

The μA723 is designed for use in positive or negative power supplies as a series, shunt, switching, or floating regulator. For output currents exceeding 150 mA, additional pass elements can be connected as shown in Figures 4 and 5.

The μA723C is characterized for operation from 0°C to 70°C.

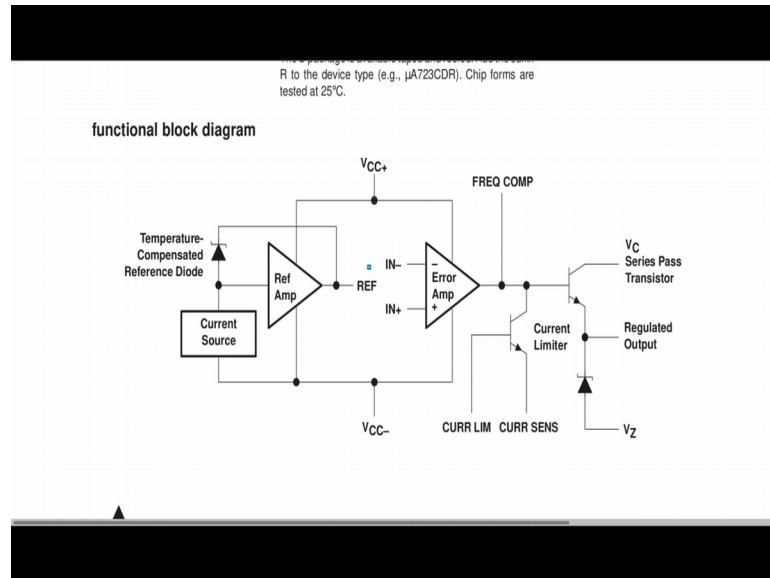
AVAILABLE OPTIONS

D OR N PACKAGE (TOP VIEW)

NC	1	14	NC
CURR LIM	2	13	FREQ COMP
CURR SENS	3	12	VCC+
IN-	4	11	VC
IN+	5	10	OUTPUT
REF	6	9	VZ
VCC-	7	8	NC

It is a 14 pinned IC. Of course, many of them are not connected, but you will see that the internal block diagram of this regulator is very similar to the discrete regulator, series regulator that we discussed.

(Refer Slide Time: 03:23)



And you will see that many of the features that we have discussed is already implemented in IC form in this regulator. And you can make the best use of it.

(Refer Slide Time: 03:38)

SLVS057D – AUGUST 1972 – REVISED JULY 1999

recommended operating conditions

	MIN	MAX	UNIT
Input voltage, V_I	9.5	40	V
Output voltage, V_O	2	37	V
Input-to-output voltage differential, $V_C - V_O$	3	38	V
Output current, I_O		150	mA
Operating free-air temperature range, T_A	$\mu\text{A}723\text{C}$	0	70 °C

electrical characteristics at specified free-air temperature (see Notes 3 and 4)

PARAMETER	TEST CONDITIONS	T_A	$\mu\text{A}723\text{C}$			UNIT
			MIN	TYP	MAX	
Input regulation	$V_I = 12\text{ V to } V_I = 15\text{ V}$	25°C	0.1	1		mV/V
	$V_I = 12\text{ V to } V_I = 40\text{ V}$	25°C	1	5		
	$V_I = 12\text{ V to } V_I = 15\text{ V}$	0°C to 70°C			3	
Ripple rejection	$f = 50\text{ Hz to } 10\text{ kHz}, C_{\text{ref}} = 0$	25°C		74		dB
	$f = 50\text{ Hz to } 10\text{ kHz}, C_{\text{ref}} = 5\ \mu\text{F}$	25°C		86		
Output regulation		25°C	-0.3	-2		mV/V
		0°C to 70°C		-6		

Here are some data sheet values, input voltage 9.5 to 40 volts max. So, let us stay within that for an output voltage. See 723 is a variable precision regulator, you can set for

different output voltage from 2 to 37 volts. Input-output differential voltage this is an important parameter, so not exceed input-output differential voltage of 38 volts, and you should keep a minimum of 3 volts. And you have a 150 milliamp output current possibility.

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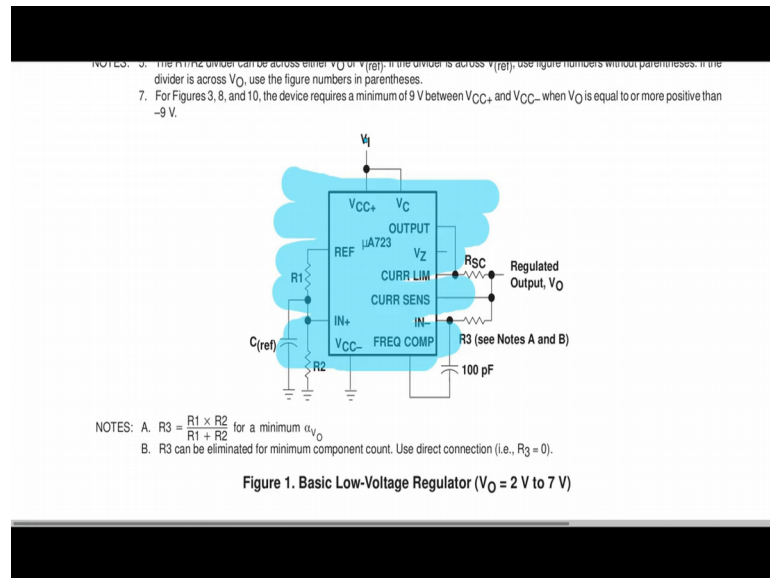
Operating free-air temperature range, T_A		$\mu A723C$	0	70	$^{\circ}C$	
electrical characteristics at specified free-air temperature (see Notes 3 and 4)						
PARAMETER	TEST CONDITIONS	T_A	$\mu A723C$		UNIT	
			MIN	TYP		MAX
Input regulation	$V_I = 12\text{ V to } V_I = 15\text{ V}$	$25^{\circ}C$	0.1	1	mV/V	
	$V_I = 12\text{ V to } V_I = 40\text{ V}$	$25^{\circ}C$	1	5		
	$V_I = 12\text{ V to } V_I = 15\text{ V}$	$0^{\circ}C\text{ to } 70^{\circ}C$		3		
Ripple rejection	$f = 50\text{ Hz to } 10\text{ kHz}, C_{ref} = 0$	$25^{\circ}C$		74	dB	
	$f = 50\text{ Hz to } 10\text{ kHz}, C_{ref} = 5\ \mu F$	$25^{\circ}C$		86		
Output regulation		$25^{\circ}C$	-0.3	-2	mV/V	
		$0^{\circ}C\text{ to } 70^{\circ}C$		-6		
Reference voltage, V_{ref}		$25^{\circ}C$	6.8	7.15	7.5	V
Standby current	$V_I = 30\text{ V}, I_O = 0$	$25^{\circ}C$	2.3	4		mA
Temperature coefficient of output voltage*		$0^{\circ}C\text{ to } 70^{\circ}C$	0.003	0.015		%/ $^{\circ}C$
Short-circuit output current	$R_{SC} = 10\ \Omega, V_O = 0$	$25^{\circ}C$	65			mA
Output noise voltage	$BW = 100\text{ Hz to } 10\text{ kHz}, C_{ref} = 0$	$25^{\circ}C$		20		μV
	$BW = 100\text{ Hz to } 10\text{ kHz}, C_{ref} = 5\ \mu F$	$25^{\circ}C$		2.5		

NOTES: 3. For all values in this table, the device is connected as shown in Figure 1 with the divider resistance as seen by the error amplifier $\leq 10\text{ k}\Omega$. Unless otherwise specified, $V_I = V_{CC+} = V_C = 12\text{ V}, V_{CC-} = 0, V_O = 5\text{ V}, I_O = 1\text{ mA}, R_{SC} = 0$, and $C_{ref} = 0$.

4. Pulse-testing techniques must be used that will maintain the junction temperature as close to the ambient temperature as possible.

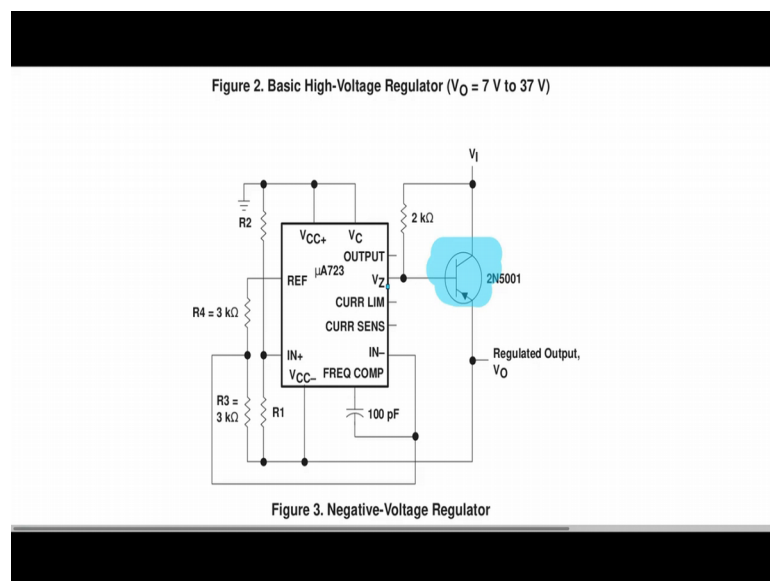
Here to look at the regulation coefficients input regulation. One typically 1 and maximum of 5 millivolt per volt, ripple rejection, output regulation, and you have the temperature coefficient output voltage. Now, these are the important parameters that you should consider in doing your design.

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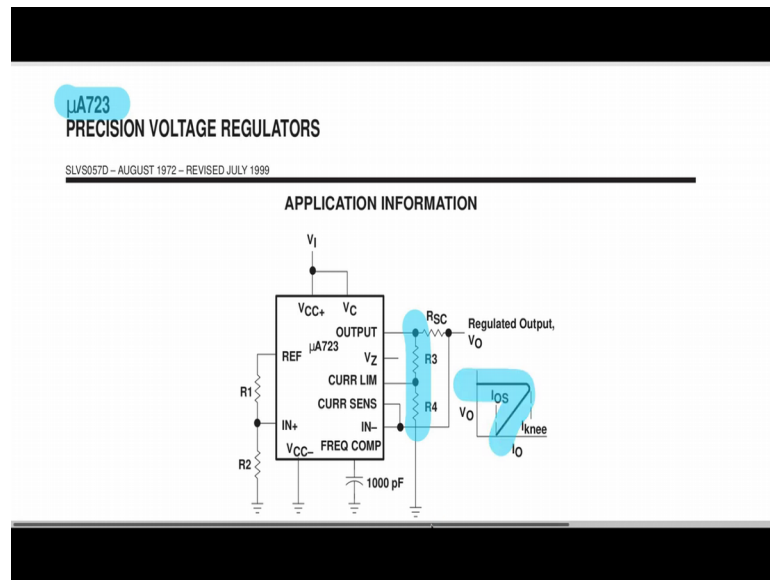
Look at this, this is a typical circuit given in the data sheet for the 723 regulator. So, this is where unregulated V_i is given. And internally reference is generated; you do not need to put an external zener. So, internal reference can be used and given to the plus terminal of the op amp internal op amp. Even the op amp is internal, and to the minus terminal you will give the output that is fed back. And there is a facility to add RSC short circuit protection or the current limit through this across these terminals when you have the current SENS. So, this is a typical case what we discussed in the discrete version.

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LM 723 also provides you with facility to provide an output transistor, transistor on the output side to provide a current boost. Let us say this internal transistor is capable of taking 150 milliamps, and you want 1 amp at the output load current you can put a current boost and then increase the current capability.

(Refer Slide Time: 05:51)



Observe again from the data sheet of muA 7 723, they have implemented the fold back current limiting. The transistors are internal. The resistance you have to put external, and you see the fold back current limiting operation.

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LM317
SLVS044X – SEPTEMBER 1997 – REVISED SEPTEMBER 2016

LM317 3-Terminal Adjustable Regulator

1 Features

- Output Voltage Range Adjustable From 1.25 V to 37 V
- Output Current Greater Than 1.5 A
- Internal Short-Circuit Current Limiting
- Thermal Overload Protection
- Output Safe-Area Compensation

2 Applications

- ATCA Solutions
- DLP: 3D Biometrics, Hyperspectral Imaging, Optical Networking, and Spectroscopy
- DVR and DVS
- Desktop PC
- Digital Signage and Still Camera

3 Description

The LM317 device is an adjustable three-terminal positive-voltage regulator capable of supplying more than 1.5 A over an output-voltage range of 1.25 V to 37 V. It requires only two external resistors to set the output voltage. The device features a typical line regulation of 0.01% and typical load regulation of 0.1%. It includes current limiting, thermal overload protection, and safe operating area protection. Overload protection remains functional even if the ADJUST terminal is disconnected.

Device Information⁽¹⁾

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LM317DCY	SOT-223 (4)	6.50 mm × 3.50 mm
LM317KCS	TO-220 (3)	10.16 mm × 9.15 mm
LM317KCT	TO-220 (3)	10.16 mm × 8.59 mm

LM317 is another 3-terminal adjustable regulator. I will discuss this a bit more in detail later. Another version of LM317 called the LM350 is also a 3-terminal regulator. LM317 has 1.5 amp output current rating, whereas LM350 has 3 amp rating. So, they are powerful regulators for quite reasonable amount of power.

(Refer Slide Time: 06:46)

Package	Part Number	Dimensions
SOT-223 (4)	LM317DCY	6.50 mm x 3.50 mm
TO-220 (3)	LM317KCS	10.16 mm x 9.15 mm
TO-220 (3)	LM317KCT	10.16 mm x 8.59 mm
TO-263 (3)	LM317KTT	10.16 mm x 9.01 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

Battery-Charger Circuit

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Here too you have just 3-terminals, the input, the output and the adjust. There is a fixed, there is a fixed voltage between the output and the adjust and that is used as the reference voltage and that is what is used for at achieving adjustable output voltage regulator.

(Refer Slide Time: 07:06)

6.5 Electrical Characteristics

over recommended ranges of operating virtual junction temperature (unless otherwise noted)

PARAMETER	TEST CONDITIONS ⁽¹⁾	MIN	TYP	MAX	UNIT	
Line regulation ⁽²⁾	$V_I - V_O = 3 \text{ V to } 40 \text{ V}$	$T_J = 25^\circ\text{C}$	0.01	0.04	%V	
		$T_J = 0^\circ\text{C to } 125^\circ\text{C}$	0.02	0.07		
Load regulation	$I_O = 10 \text{ mA to } 1500 \text{ mA}$	$C_{ADJ}^{(3)} = 10 \mu\text{F}$, $T_J = 25^\circ\text{C}$	$V_O \leq 5 \text{ V}$	0.1	0.5	mV
			$V_O \geq 5 \text{ V}$	20	70	mV
		$T_J = 0^\circ\text{C to } 125^\circ\text{C}$	$V_O \leq 5 \text{ V}$	0.3	1.5	% V_O
			$V_O \geq 5 \text{ V}$	0.03	0.07	% V_O
Thermal regulation	20-ms pulse, $T_J = 25^\circ\text{C}$		0.03	0.07	% V_O /W	
ADJUST terminal current			50	100	μA	
Change in ADJUST terminal current	$V_I - V_O = 2.5 \text{ V to } 40 \text{ V}$, $P_D \leq 20 \text{ W}$, $I_O = 10 \text{ mA to } 1500 \text{ mA}$		0.2	5	μA	
Reference voltage	$V_I - V_O = 3 \text{ V to } 40 \text{ V}$, $P_D \leq 20 \text{ W}$, $I_O = 10 \text{ mA to } 1500 \text{ mA}$	1.2	1.25	1.3	V	
Output-voltage temperature stability	$T_J = 0^\circ\text{C to } 125^\circ\text{C}$		0.7		% V_O	
Minimum load current to maintain regulation	$V_I - V_O = 40 \text{ V}$		3.5	10	mA	
Maximum output current	$V_I - V_O \leq 15 \text{ V}$, $P_D < P_{D\text{MAX}}^{(4)}$	1.5	2.2		A	
	$V_I - V_O \leq 40 \text{ V}$, $P_D < P_{D\text{MAX}}^{(4)}$, $T_J = 25^\circ\text{C}$	0.15	0.4			
RMS output noise voltage (% of V_O)	$f = 10 \text{ Hz to } 10 \text{ kHz}$, $T_J = 25^\circ\text{C}$		0.003		% V_O	

In the electrical characteristics of the data sheet you see for the LM317 line regulation aspect, it is given here, terms of percent per volt, you have the load regulation given here, thermal regulation. So, all these aspects are given, and you will have to map it to the regulation equation that we discussed.

(Refer Slide Time: 07:36)

Parameter	Conditions	Typical	Max	Unit	
Thermal regulation	20-ms pulse, $T_J = 25^\circ\text{C}$	0.03	0.07	% V_O/W	
ADJUST terminal current		50	100	μA	
Change in ADJUST terminal current	$V_I - V_O = 2.5\text{ V to } 40\text{ V}$, $P_D \leq 20\text{ W}$, $I_O = 10\text{ mA to } 1500\text{ mA}$	0.2	5	μA	
Reference voltage	$V_I - V_O = 3\text{ V to } 40\text{ V}$, $P_D \leq 20\text{ W}$, $I_O = 10\text{ mA to } 1500\text{ mA}$	1.2	1.25	1.3	V
Output-voltage temperature stability	$T_J = 0^\circ\text{C to } 125^\circ\text{C}$	0.7		% V_O	
Minimum load current to maintain regulation	$V_I - V_O = 40\text{ V}$	3.5	10	mA	
Maximum output current	$V_I - V_O \leq 15\text{ V}$, $P_D < P_{D\text{MAX}}^{(4)}$	1.5	2.2	A	
	$V_I - V_O \leq 40\text{ V}$, $P_D < P_{D\text{MAX}}^{(4)}$, $T_J = 25^\circ\text{C}$	0.15	0.4		
RMS output noise voltage (% of V_O)	$f = 10\text{ Hz to } 10\text{ kHz}$, $T_J = 25^\circ\text{C}$	0.003		% V_O	
Ripple rejection	$V_O = 10\text{ V}$, $f = 120\text{ Hz}$		57	dB	
	$C_{\text{ADJ}} = 0\ \mu\text{F}^{(3)}$		62		
	$C_{\text{ADJ}} = 10\ \mu\text{F}^{(3)}$		64		
Long-term stability	$T_J = 25^\circ\text{C}$	0.3	1	%/1k hr	

(1) Unless otherwise noted, the following test conditions apply: $V_I - V_O = 5\text{ V}$ and $I_{\text{O MAX}} = 1.5\text{ A}$, $T_J = 0^\circ\text{C to } 125^\circ\text{C}$. Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible.
(2) Line regulation is expressed here as the percentage change in output voltage per 1-V change at the input.
(3) C_{ADJ} is connected between the ADJUST terminal and GND.
(4) Maximum power dissipation is a function of $T_J(\text{max})$, θ_{JA} , and T_A . The maximum allowable power dissipation at any allowable ambient temperature is $P_D = (T_J(\text{max}) - T_A) / \theta_{\text{JA}}$. Operating at the absolute maximum T_J of 150°C can affect reliability.

Another important aspect that you need to note that in most of the data sheets you will find R theta JA junction to ambient thermal resistance.

(Refer Slide Time: 07:40)

T_J Operating virtual junction temperature		0	125	$^\circ\text{C}$	
6.4 Thermal Information					
THERMAL METRIC ⁽¹⁾	LM317				UNIT
	DCY (SOT-223) 4 PINS	KCS (TO-220) 3 PINS	⁹ KCT (TO-220) 3 PINS	KTT (TO-263) 3 PINS	
$R_{\theta(\text{JA})}$ Junction-to-ambient thermal resistance	66.8	23.5	37.9	38.0	$^\circ\text{C/W}$
$R_{\theta(\text{JC(top)})}$ Junction-to-case (top) thermal resistance	43.2	15.9	51.1	36.5	$^\circ\text{C/W}$
$R_{\theta(\text{JB})}$ Junction-to-board thermal resistance	16.9	7.9	23.2	18.9	$^\circ\text{C/W}$
$V_{\theta(\text{JT})}$ Junction-to-top characterization parameter	3.6	3.0	13.0	6.9	$^\circ\text{C/W}$
$V_{\theta(\text{JB})}$ Junction-to-board characterization parameter	16.8	7.8	22.8	17.9	$^\circ\text{C/W}$
$R_{\theta(\text{JC(bot)})}$ Junction-to-case (bottom) thermal resistance	NA	0.1	4.2	1.1	$^\circ\text{C/W}$

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report.

So, from the core, the core of the regulator should not cross 150 degree centigrade; and to be on the safe side we set it at 120 degree centigrade and pass on the heat to the ambient. How do you pass on the heat to the ambient? You can use thermal resistance is given here in degree centigrade per watt. If they do not give reasonable thermal flow, you may have to put extra additional heat sinks, now that is very very important if any of your regulators or semiconductor devices has to function properly.