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

Lecture – 42
Datasheet of few IC regulators

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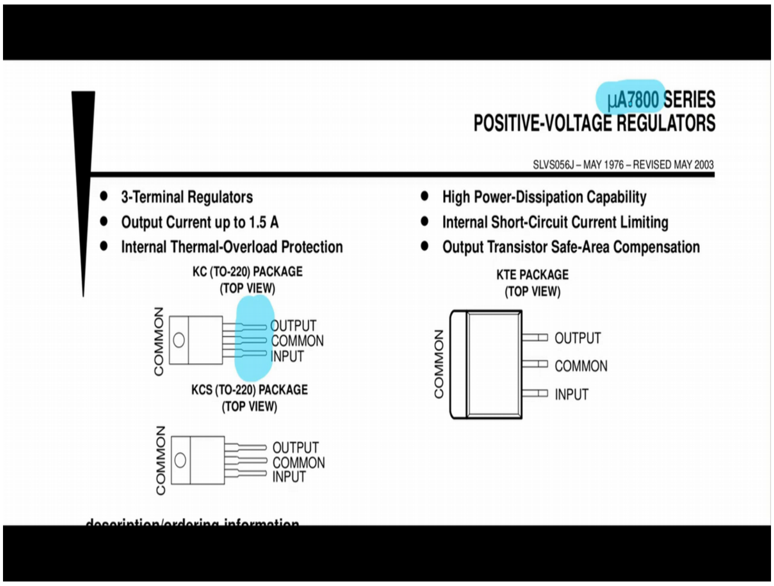

Let us look at some commercial linear regulators. The mu A78 series regulator is a very popular and commonly available linear regulator. It is a 3-pin you see here 3-pin, 3-terminal linear regulator. You have a input the output and the common pin very popular, and it comes in various fixed outputs 78xx 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.

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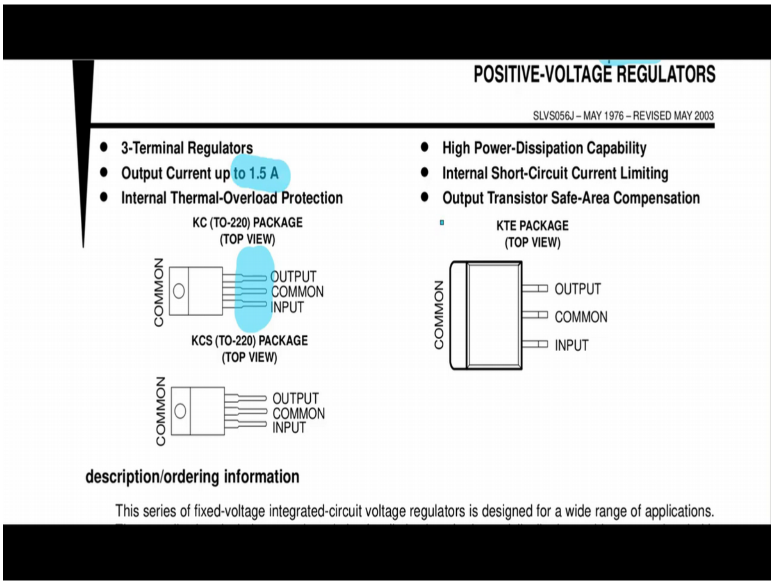

Very popular output currents up to 1.5 amps, and it is available in TO-220 package.

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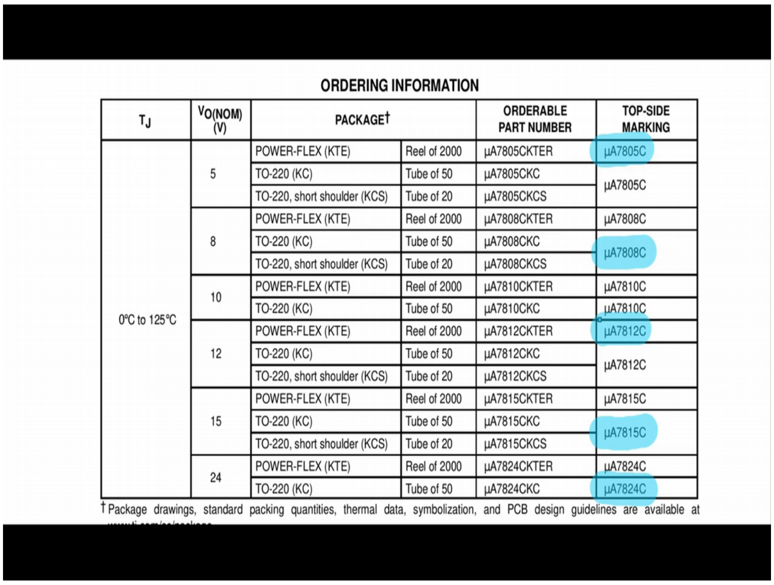

ORDERING INFORMATION

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	µA7805CKTER	µA7805C
		TO-220 (KC)	Tube of 50	µA7805CKC	µA7805C
		TO-220, short shoulder (KCS)	Tube of 20	µA7805CKCS	
	8	POWER-FLEX (KTE)	Reel of 2000	µA7808CKTER	µA7808C
		TO-220 (KC)	Tube of 50	µA7808CKC	µA7808C
		TO-220, short shoulder (KCS)	Tube of 20	µA7808CKCS	
	10	POWER-FLEX (KTE)	Reel of 2000	µA7810CKTER	µA7810C
		TO-220 (KC)	Tube of 50	µA7810CKC	µA7810C
	12	POWER-FLEX (KTE)	Reel of 2000	µA7812CKTER	µA7812C
		TO-220 (KC)	Tube of 50	µA7812CKC	µA7812C
		TO-220, short shoulder (KCS)	Tube of 20	µA7812CKCS	
	15	POWER-FLEX (KTE)	Reel of 2000	µA7815CKTER	µA7815C
		TO-220 (KC)	Tube of 50	µA7815CKC	µA7815C
		TO-220, short shoulder (KCS)	Tube of 20	µA7815CKCS	
	24	POWER-FLEX (KTE)	Reel of 2000	µA7824CKTER	µA7824C
		TO-220 (KC)	Tube of 50	µA7824CKC	µA7824C

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at

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.

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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

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.

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PARAMETER	TEST CONDITIONS	T_J†	MIN	TYP	MAX	UNIT
	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.

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

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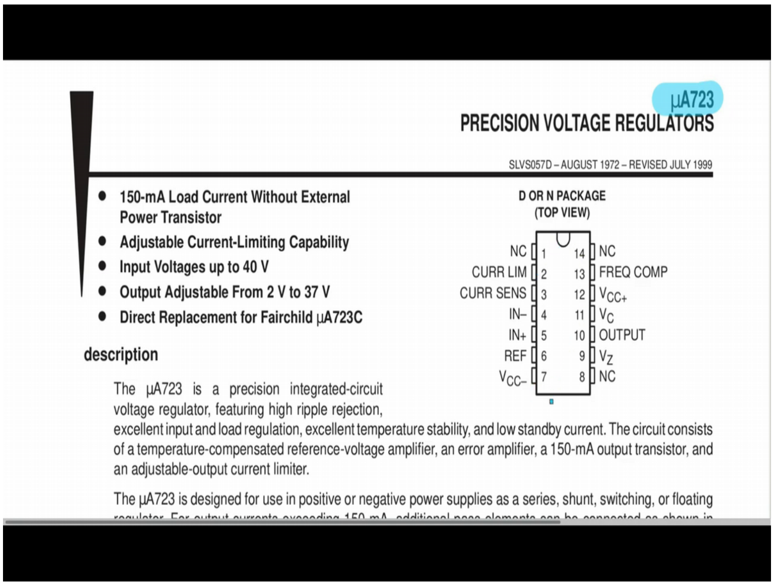

Another versatile precision regulator available in the market is the 7803.7 Another versatile precision regulator available in the market is the muA723. It comes in a d package and few other packages as well.

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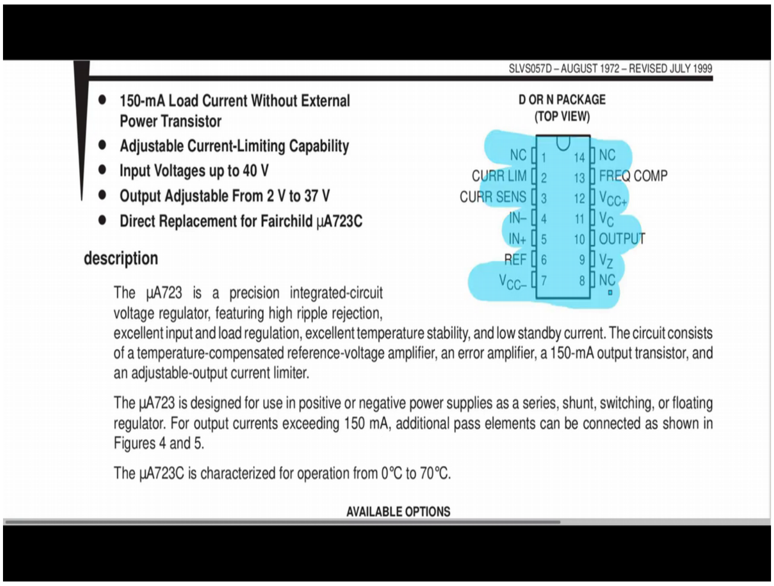

It is a 14 pinned IC. Of course, many of them are not connected, but you will see that the internal block diagram of this regulator is very similar to the discrete regulator, series regulator that we discussed.

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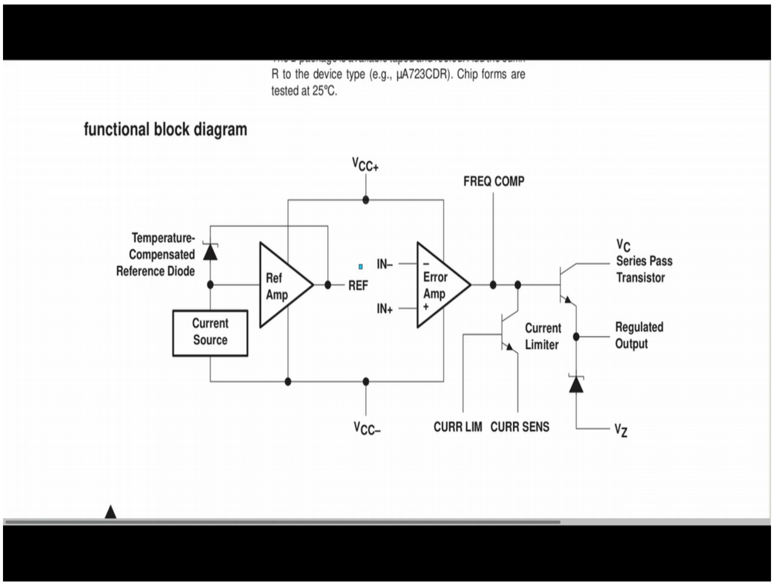

And you will see that many of the features that we have discussed is already implemented in IC form in this regulator. And you can make the best use of it.

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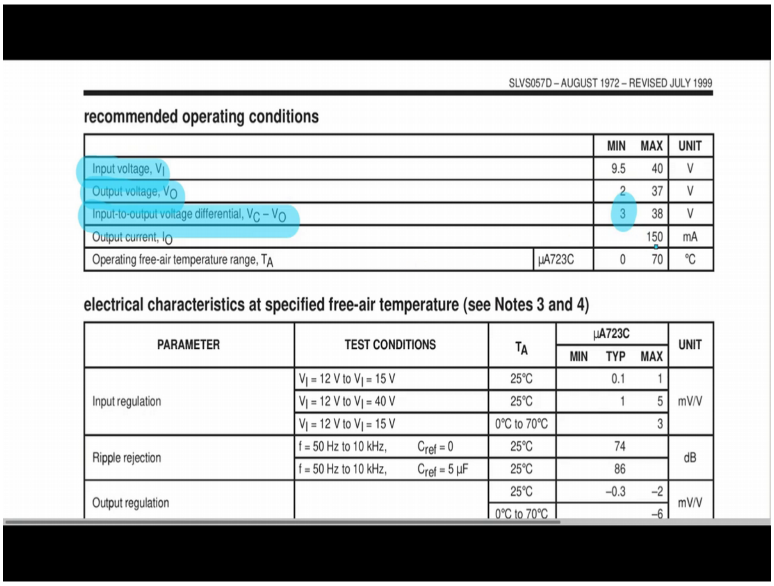
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recommended operating conditions

		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	µA723C	0	70	°C

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

PARAMETER	TEST CONDITIONS	T_A	µA723C MIN	µA723C TYP	µA723C MAX	UNIT
Input regulation	V_I = 12 V to V_I = 15 V	25°C		0.1	1	mV/V
	V_I = 12 V to V_I = 40 V	25°C		1	5	
	V_I = 12 V to V_I = 15 V	0°C to 70°C			3	
Ripple rejection	f = 50 Hz to 10 kHz, C_{ref} = 0	25°C		74		dB
	f = 50 Hz to 10 kHz, C_{ref} = 5 µF	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	μA723C	0	70	°C

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

PARAMETER	TEST CONDITIONS		T_A	μA723C			UNIT
				MIN	TYP	MAX	
Input regulation	V_I = 12 V to V_I = 15 V		25°C		0.1	1	mV/V
	V_I = 12 V to V_I = 40 V		25°C		1	5	
	V_I = 12 V to V_I = 15 V		0°C to 70°C			3	
Ripple rejection	f = 50 Hz to 10 kHz,	C_{ref} = 0	25°C		74		dB
	f = 50 Hz to 10 kHz,	C_{ref} = 5 μF	25°C		86		
Output regulation			25°C		−0.3	−2	mV/V
			0°C to 70°C			−6	
Reference voltage, V_{ref}			25°C	6.8	7.15	7.5	V
Standby current	V_I = 30 V,	I_O = 0	25°C		2.3	4	mA
Temperature coefficient of output voltage			0°C to 70°C		0.003	0.015	%/°C
Short-circuit output current	R_{SC} = 10 Ω,	V_O = 0	25°C		65		mA
Output noise voltage	BW = 100 Hz to 10 kHz,	C_{ref} = 0	25°C		20		μV
	BW = 100 Hz to 10 kHz,	C_{ref} = 5 μF	25°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 ≤10 kΩ. Unless otherwise specified, $V_I = V_{CC+} = V_C$ = 12 V, V_{CC-} = 0, V_O = 5 V, I_O = 1 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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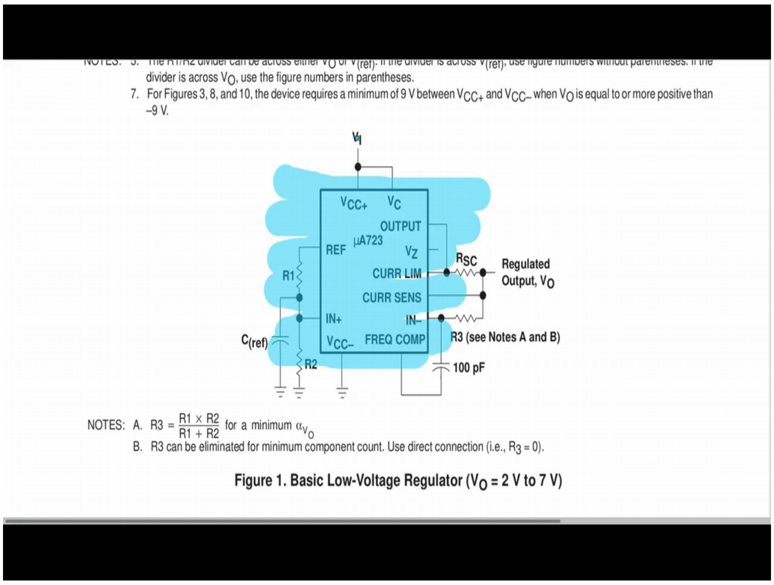

Look at this, this is a typical circuit given in the data sheet for the 723 regulator. So, this is where unregulated V i is given. And internally reference is generated; you do not need to put an external zener. So, internal reference can be used and given to the plus terminal of the op amp internal 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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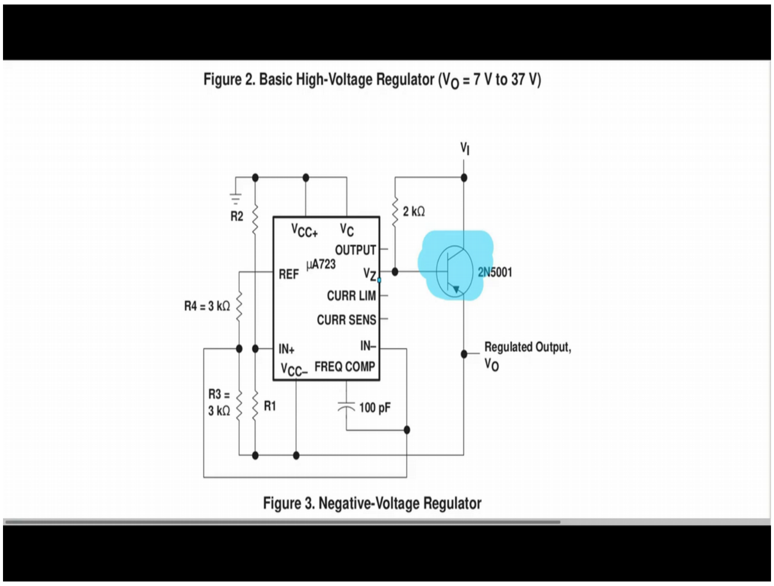

LM 723 also provides you with facility to provide an output transistor, transistor on the output side to provide a current boost. Let us say this internal transistor is capable of taking 150 milliamps, and you want 1 amp at the output load current you can put a current boost and then increase the current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

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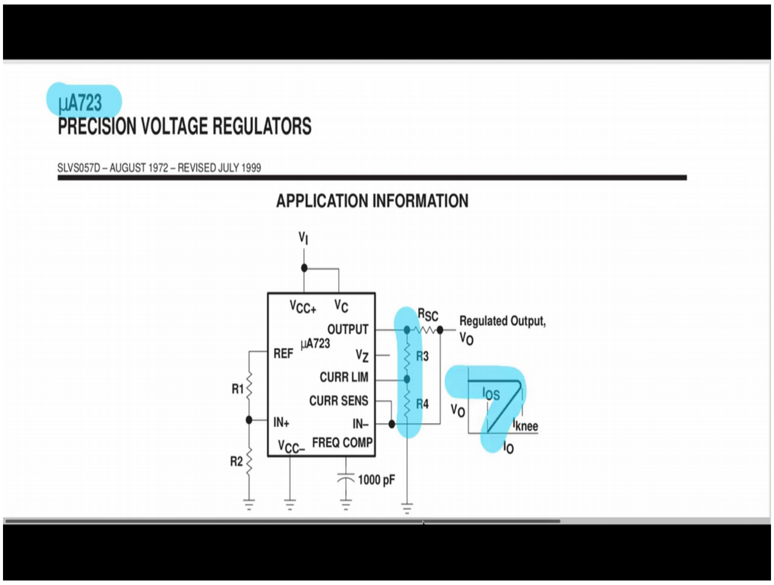

Observe again from the data sheet of muA 7 723, they have implemented the fold back current limiting. The transistors are internal. The resistance you have to put external, and you see the fold back current limiting operation.

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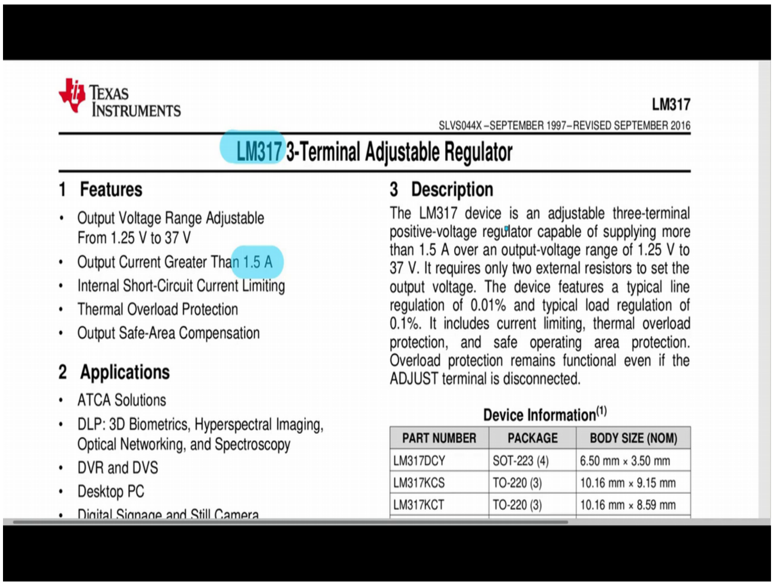

LM317 is another 3-terminal adjustable regulator. I will discuss this a bit more in detail later. Another version of LM317 called the LM350 is also a 3-terminal regulator. LM317 has 1.5 amp output current rating, whereas LM350 has 3 amp rating. So, they are powerful regulators for quite reasonable amount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

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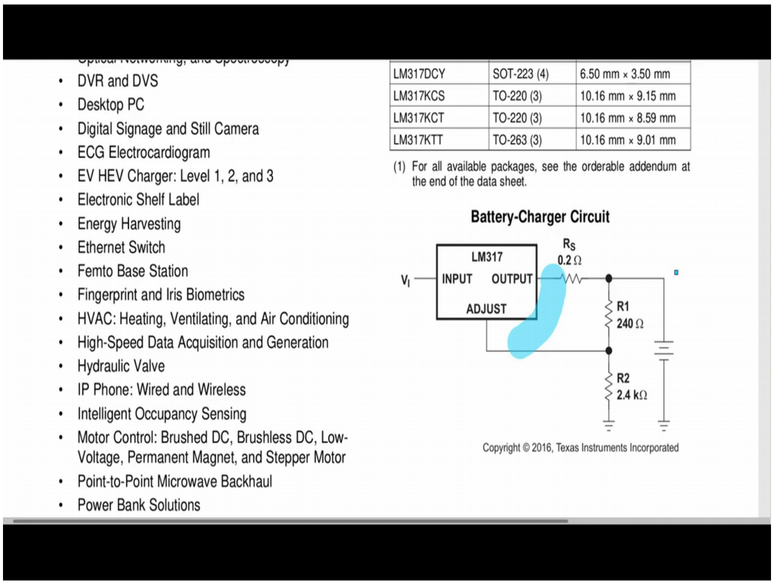

Here too you have just 3-terminals, the input, output and the adjust. There is a fixed, there is a fixed voltage between the output and the adjust and that is used as the reference voltage and that is what is used for at achieving adjustable output voltage regulator.

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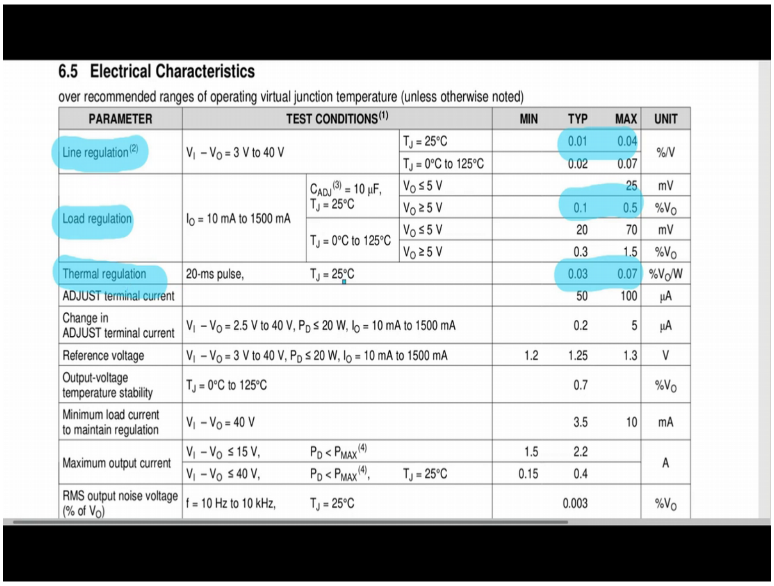

6.5 Electrical Characteristics

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 V to 40 V		T_J = 25°C		0.01	0.04	%/V
			T_J = 0°C to 125°C		0.02	0.07	
Load regulation	I_O = 10 mA to 1500 mA	C_{ADJ}(3) = 10 µF, T_J = 25°C	$V_O \le 5$ V			25	mV
			$V_O \ge 5$ V		0.1	0.5	%V_O
		T_J = 0°C to 125°C	$V_O \le 5$ V		20	70	mV
			$V_O \ge 5$ V		0.3	1.5	%V_O
Thermal regulation	20-ms pulse,	T_J = 25°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 V to 40 V, $P_D \le 20$ W, I_O = 10 mA to 1500 mA				0.2	5	µA
Reference voltage	$V_I - V_O$ = 3 V to 40 V, $P_D \le 20$ W, I_O = 10 mA to 1500 mA			1.2	1.25	1.3	V
Output-voltage temperature stability	T_J = 0°C to 125°C				0.7		%V_O
Minimum load current to maintain regulation	$V_I - V_O$ = 40 V				3.5	10	mA
Maximum output current	$V_I - V_O \le 15$ V,	$P_D < P_{MAX}$(4)		1.5	2.2		A
	$V_I - V_O \le 40$ V,	$P_D < P_{MAX}$(4),	T_J = 25°C	0.15	0.4		
RMS output noise voltage (% of V_O)	f = 10 Hz to 10 kHz,	T_J = 25°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.

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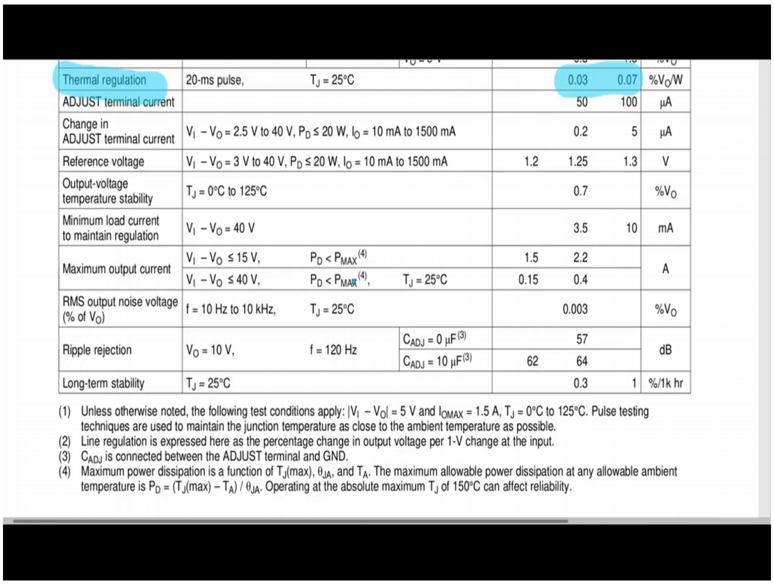

Another important aspect that you need to note that in most of the data sheets you will find R theta JA junction to ambient thermal resistance.

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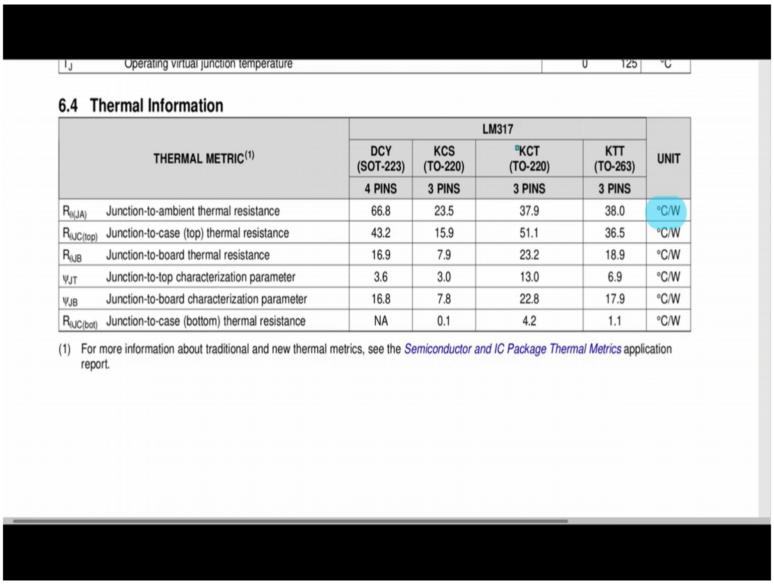

So, from the core, the core of the regulator should not cross 150 degree centigrade; and to be on the safe side we set it at 120 degree centigrade and pass on the heat to the ambient. How do you pass on the heat to the ambient? You can use thermal resistance is given here in degree centigrade per watt. 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.