EE682 – Group Project Design

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Lecture on Design of a Static Switching

Design Steps

1. Select a switching transistor;
2. Analyze to determine maximum steady state and transient device voltage and current over expected range of operating conditions;
3. Thermal analysis to establish the worst-case device junction temperature
4. Study transistor data sheet
    - Only worst-case data are published
    - Contacting application engineers of device manufacturers

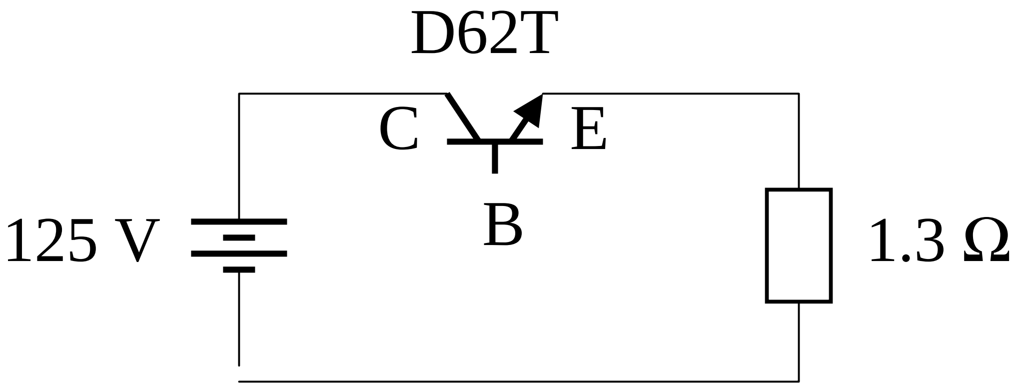
Low Frequency Design

1. Switching losses are small
    - This is the case for static switch, choppers, buck converters
    - Switching device is on and off for a short period

Example

Requirements:

- Supply voltage 125 V
- Load R = 1.3 Ω



Transistor selection:

D62T: 400-500 V switch, frequency of switching = 100 kHz

Is this a good selection?

Example

No → It is not economical. Since D62T can switch of 400-500V.

However → It is a good choice since the thermal losses are low due to operating at 125 V.

Assumptions:

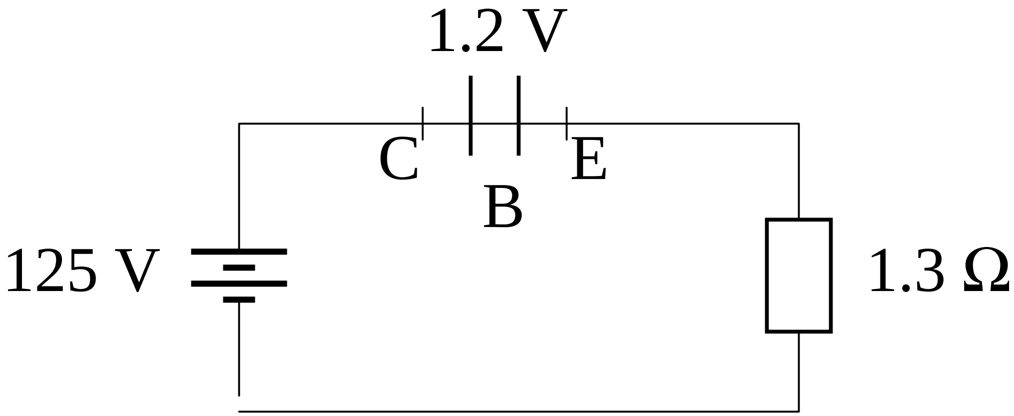
- Off-state losses are small;
- Base drive losses are not very small, but they are considerable smaller than that of on-state;
- Base driver losses are neglected;
- Switch is on for a long time.

Assumptions

1. No second breakdown limitation
2. Negligible off-state losses
3. Negligible base drive losses
4. $V_{CE(sat)} = 1.2$ V, $I_{B1} = 20$ A

   I_{B1} is the on-state drive current (see data sheets) with junction temperature of 150^{o}C

On-state Circuit



Continuous on-state losses (P_T) in the switch is

$$P_T = \frac{125 - 1.2}{1.3} \times 1.2 = 114.28W$$

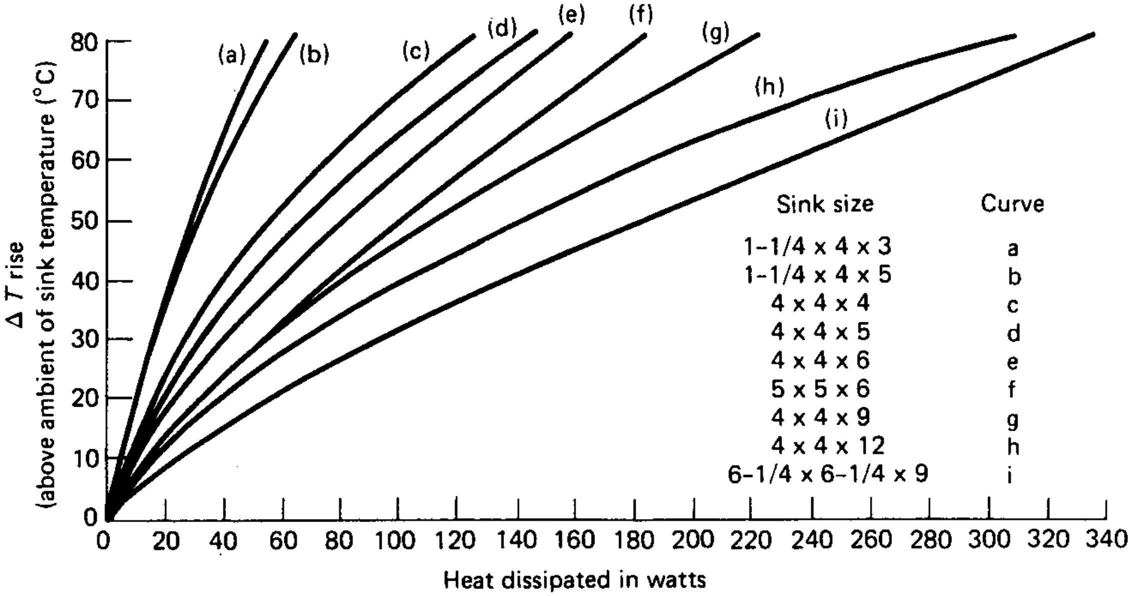
On-state Circuit

From data sheet, the thermal resistance from junction-to-sink for double-sided cooling is 0.14 ^{o}C/W

The junction-to-sink temperature different is

$$\Delta T_{js} = R_{\theta js} \times P_T = 0.14 \times 114.28 = 16^{o} C$$

Temperature rise



Sink size	Curve
1-1/4 x 4 x 3	a
1-1/4 x 4 x 5	b
4 x 4 x 4	c
4 x 4 x 5	d
4 x 4 x 6	e
5 x 5 x 6	f
4 x 4 x 9	g
4 x 4 x 12	h
6-1/4 x 6-1/4 x 9	i

Fig. 2P-2. Standard heat sink ratings* for natural convection—aluminum extrusion. *Zinc-chromate converse coating. (From Westinghouse. Used with permission)

Fig 2P-2 indicates that with two of the smaller heat sinks, curve (b) for double-sided cooling, the sink-to-ambient temperature rise would be approximately 80^{o}C with 114.28-W dissipation in switch.

Temperature rise

Therefore with an ambient temperature of 54°C, the junction temperature (T_j) is

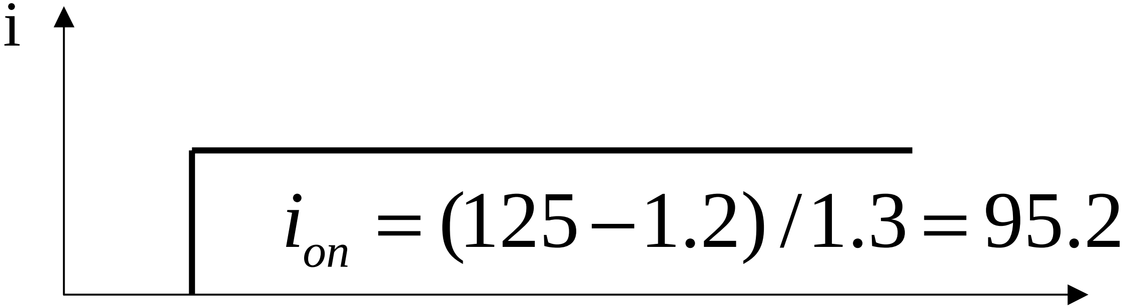
$$T_j = T_A + \Delta T_{js} + \Delta T_{sA}$$

$$= 54^o + 16^o + 80^o = 150^o C$$

$T_j \leq 150^o C$ Design OK.

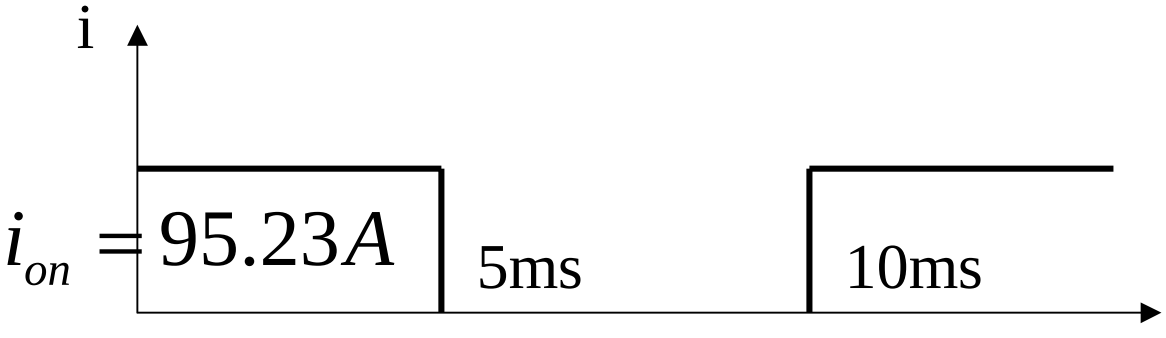
Switching Losses

Assume an on-period of 10 ms and a 50-percent duty cycle.



$$i_{on} = (125 - 1.2)/1.3 = 95.23A$$

Static switch



$$i_{on} = 95.23A$$

Low frequency chopper

Switching Losses

The switching losses for chopper is

$$P_T = V_{CE(sat)} \times I_{on} \times \frac{t_{on}}{T}$$

$$= 1.2 \times 95.23 \times \frac{1}{2} = 57.14W$$

The junction-to-sink “average” temperature is

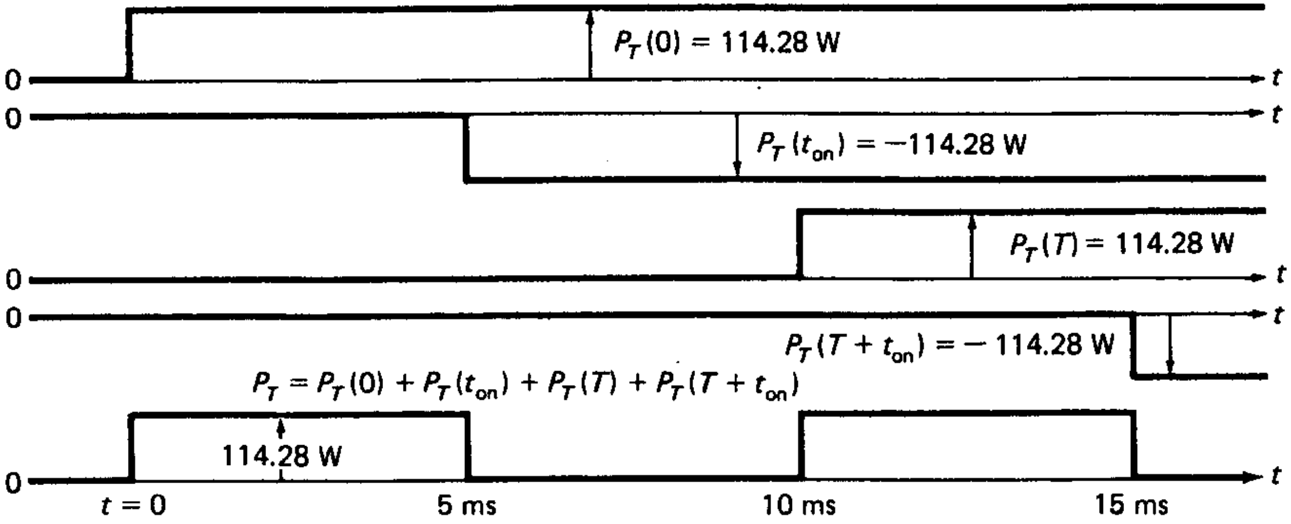
$$\Delta T_{js} = R_{\theta js} \times P_T = 0.14 \times 57.4 = 8^o C$$

Transient Variation of Junction Temperature

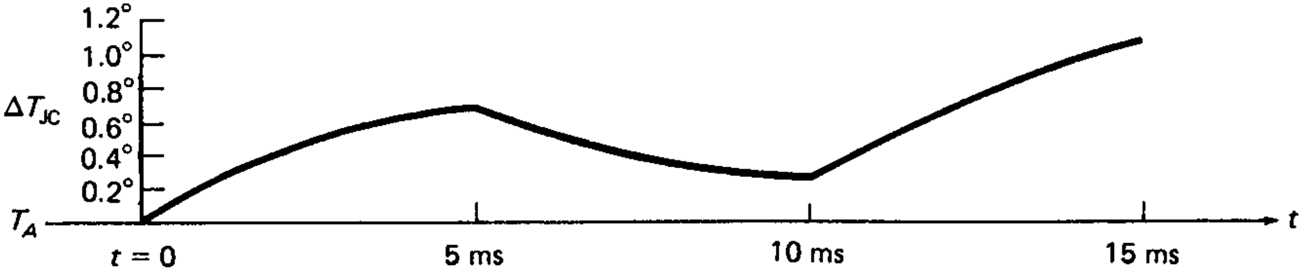
Calculation of the transient variation of junction temperature:

A step-input of power equal to the on-state loss occurs at the beginning of each switching period, and an equal but negative step-input of power takes place at the end if each on-interval.

Transient Variation of Junction Temperature



(a) Equivalent step–function representation of transistor dissipation.



(b) Transient variation in ΔT_{JC}

Fig. 2-15. Initial variation in ΔT_{JC}. (a) Equivalent step-function representation of transistor dissipation; (b) transient variation in ΔT_{JC}.

Transient Variation of Junction Temperature

The initial transient variation in the junction temperature, which is calculated as:

$$\Delta T_{jC(1ms)} = Z_{\theta jC(1ms)} \times 114.28W$$

$$= 0.003^{o}C/W \times 114.28W = 0.34^{o}C$$

$$\Delta T_{jC(3ms)} = Z_{\theta jC(3ms)} \times 114.28W$$

$$= 0.0045^{o}C/W \times 114.28W = 0.51^{o}C$$

Transient Variation of Junction Temperature

$$\Delta T_{jC(5ms)} = 0.006^{o}C/W \times 114.28W = 0.69^{o}C$$

$$\Delta T_{jC(8ms)} = [Z_{\theta jC(8ms)} - Z_{\theta jC(3ms)}] \times 114.28W$$

$$= (0.0075 - 0.0045)^{o}C/W \times 114.28W = 0.34^{o}C$$

$$\Delta T_{jC(10ms)} = [Z_{\theta jC(10ms)} - Z_{\theta jC(5ms)}] \times 114.28W$$

$$= (0.0085 - 0.006)^{o}C/W \times 114.28W = 0.29^{o}C$$

Fig 2-15 (b) shows the transient temperature.

The steady state junction temperature may be obtained by continuously the process till reaching steady state.