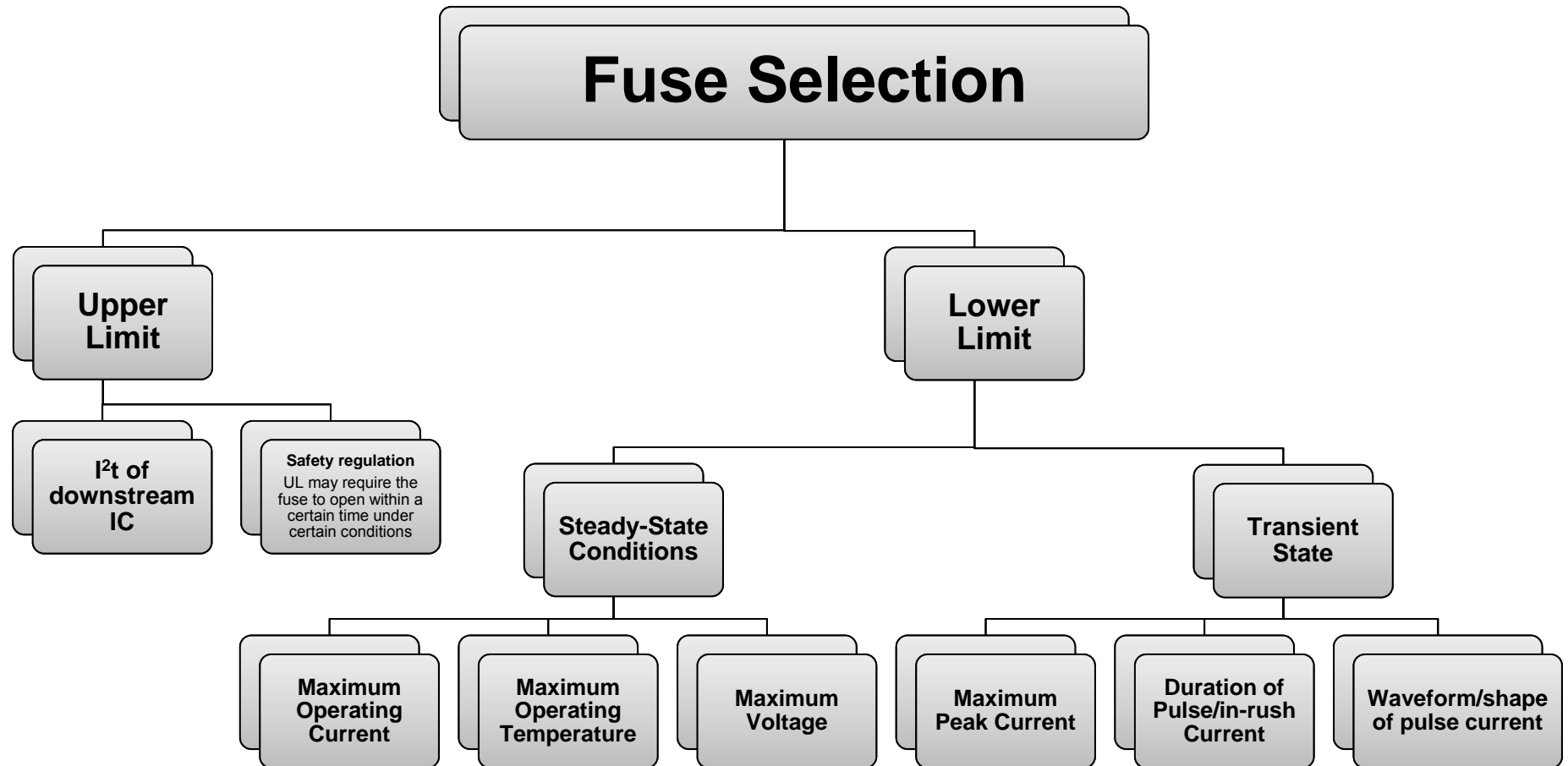
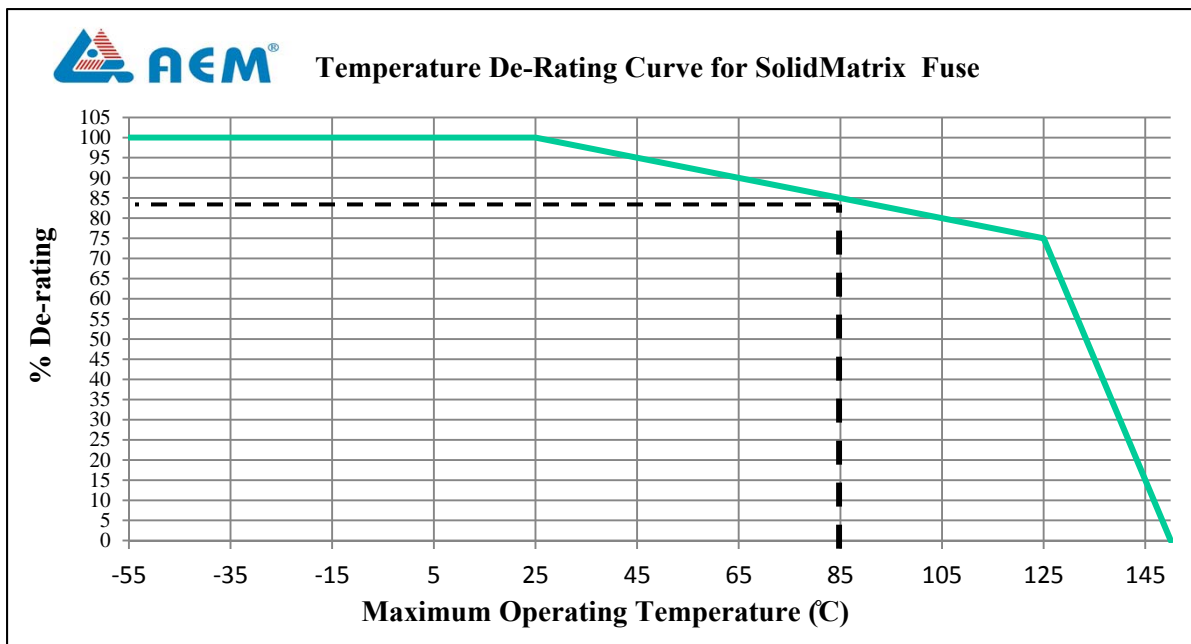


Fuses in Parallel



Steady-State



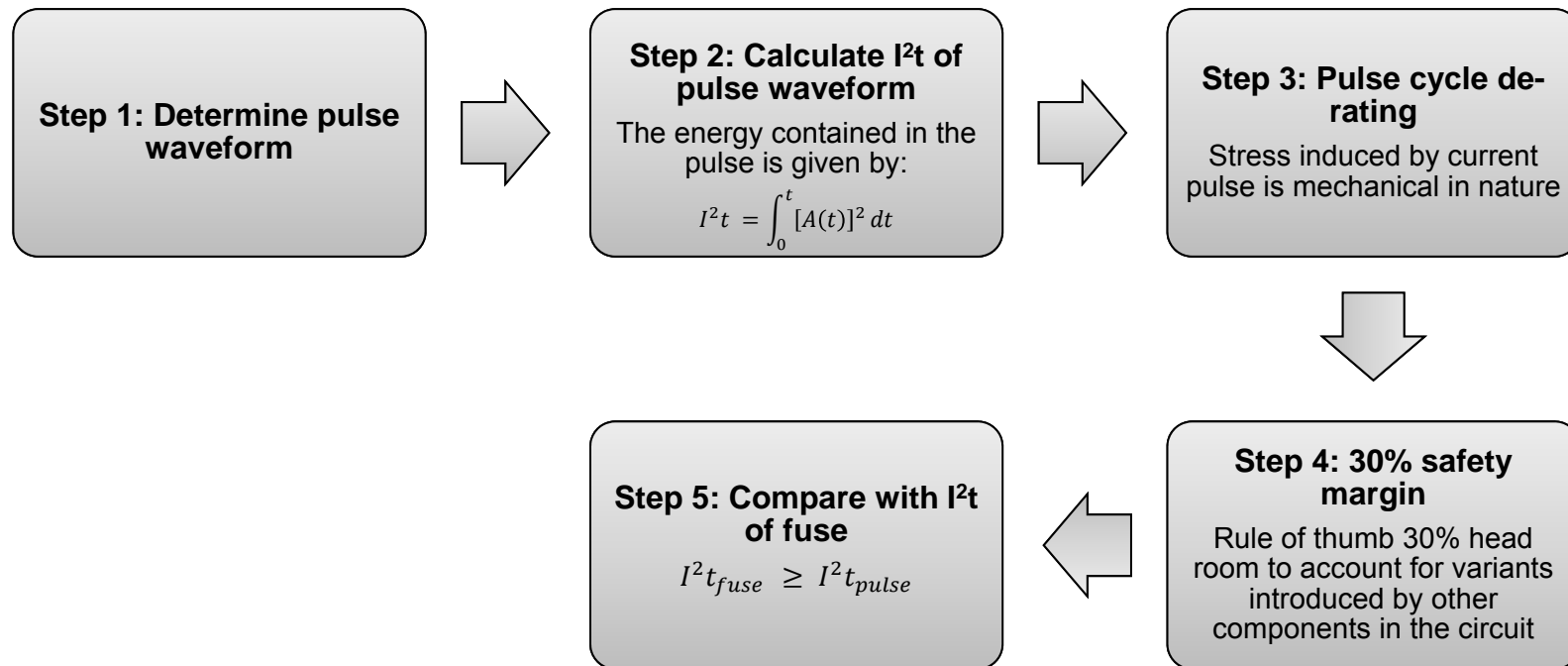
Example: Fuse current rating for a steady state operating current of 2A operating at ambient temperature up to 85°C.

$$I_{fuse} \geq \left(I_{operating} / 0.75 \right) / T_{derating}$$

$$I_{fuse} \geq \left(2 / 0.75 \right) / 0.85$$

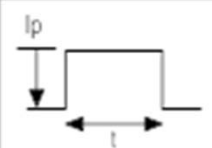
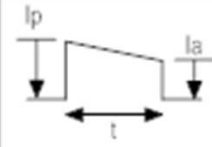
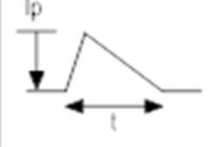
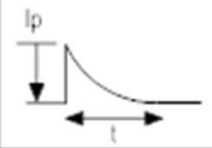
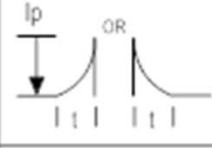
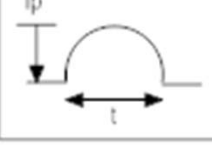
$$I_{fuse} \geq 3.13A$$

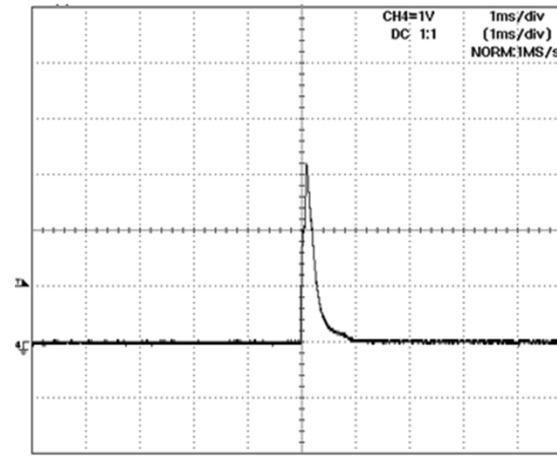
Transient State



Transient State Example

Step 1: Determine Waveform

Waveshape	Formulas
	$I^2t = I_p^2 t$
	$I^2t = \frac{1}{3}(I_p^2 + I_p I_a + I_a^2) \cdot t$
	$I^2t = \left(\frac{1}{3}\right) I_p^2 t$
	$I^2t = \left(\frac{1}{2}\right) I_p^2 t$
	$I^2t = \left(\frac{1}{5}\right) I_p^2 t$
	$I^2t = \left(\frac{1}{2}\right) I_p^2 t$



Example:
Transient pulse of capacitor discharge
100,000 cycles

Step 2: Calculate I^2t of pulse

$$I = 16A$$

$$t \approx 0.0004 \text{ sec}$$

$$\text{Pulse waveform 4} \rightarrow I^2t = \frac{I^2t}{2}$$

$$I^2t_{\text{pulse}} = \frac{(16)^2(0.0004)}{2}$$

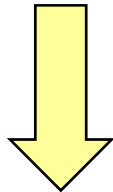
$$= 0.0512 \text{ A}^2\text{sec}$$

Transient State Example cont'd

Step 3: Pulse Cycle and Temperature de-rating

$$I^2 t_{pulse} = \frac{0.0512 A^2 sec}{0.4} =$$

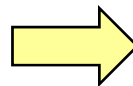
$$= \frac{0.128 A^2 sec}{0.85} = 0.15 A^2 sec$$



Step 4: 30% margin

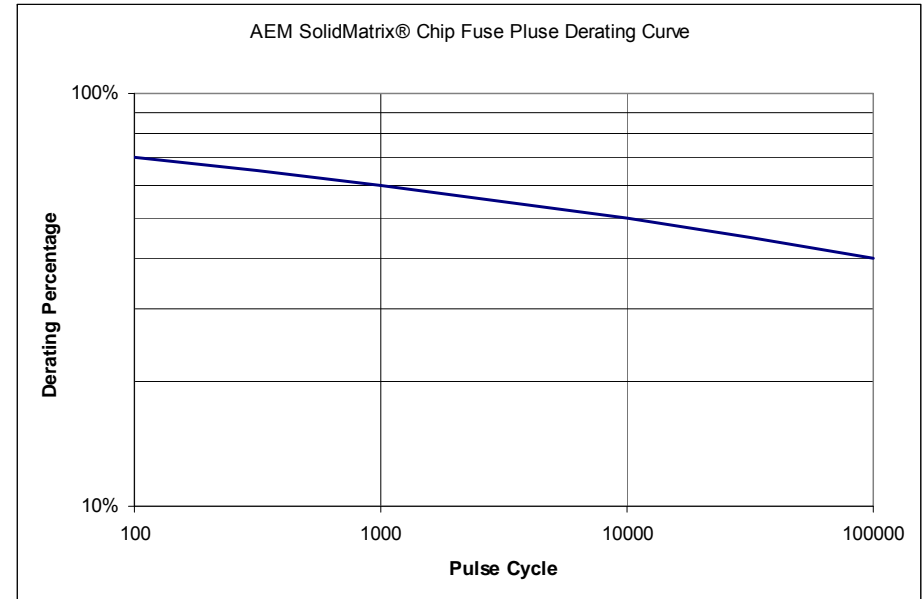
$$I^2 t_{pulse} = \frac{0.15 A^2 sec}{0.7}$$

$$= 0.215 A^2 sec @ 0.4ms$$



Step 5: Compare with I²t of fuse

$$I^2 t_{fuse} \geq I^2 t_{pulse} \rightarrow I^2 t_{fuse} \geq 0.215 A^2 sec @ 0.4ms$$



Fuses in Parallel

Concept

- Consider a parallel resistor network (Fig.1)
- i_x can be determined through equation 1
- R_T can be determined through equation 2
- Current divider

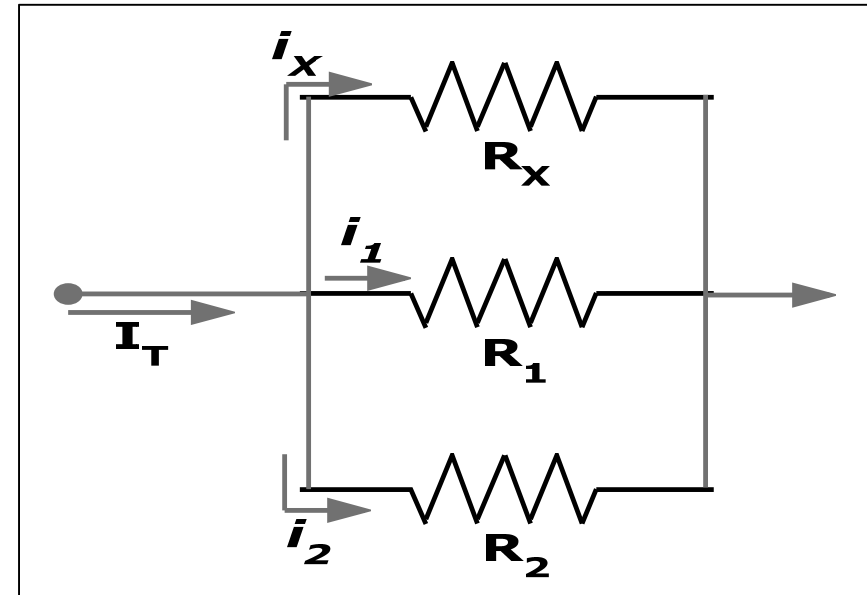


Figure 1

$$\text{Equation 1: } i_x = \frac{R_T}{R_x + R_T} I_T$$

$$\text{Equation 2: } \frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \dots \rightarrow R_T = \frac{R_1 R_2}{R_1 + R_2}$$

Fuses in Parallel

Example: Two 25A fuse in parallel (Fig. 2)

$$\left. \begin{array}{l} F_1 = 25A \text{ rated} \\ F_2 = 25A \text{ rated} \end{array} \right\} \text{DCR } \pm 30\% \text{ tolerance}$$

Steady-State

$$v_1 = v_2 \rightarrow i_1 r_1 = i_2 r_2 \rightarrow i_1 (0.7) r_1 = i_2 (1.3) r_2$$

Solve for i_2

$$i_2 = i_1 \frac{0.7}{1.3}$$

$$i_1 + i_2 = I \rightarrow i_1 + i_1 \frac{0.7}{1.3} = I \rightarrow i_1 (1.53) = I$$

$$i_1 = \frac{I}{1.53}$$

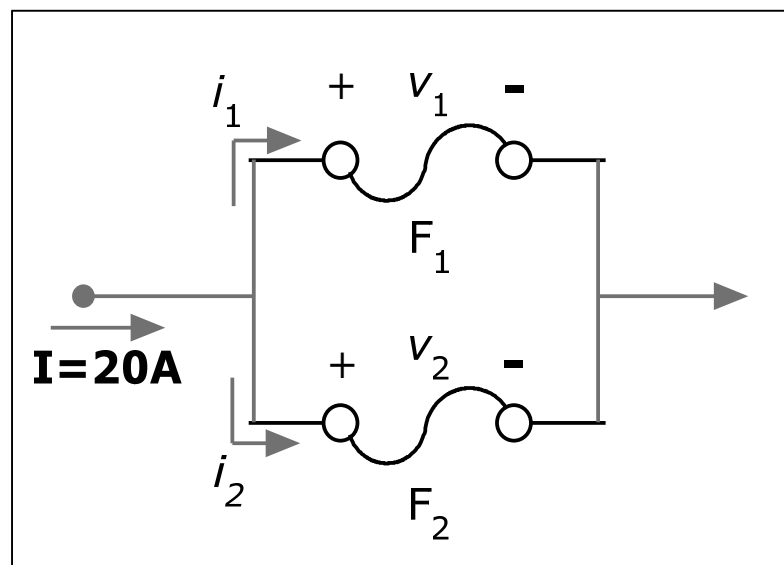


Figure 2

$$i_1 = \frac{I}{1.53} = \frac{20A}{1.53} = 13A \rightarrow \text{Operating Current derating } \frac{13A}{0.75} = 17.42A$$

$$\rightarrow \text{Temperature derating } \frac{17.42A}{0.85} = 20.5A \leq \text{fuse current rating}$$

Fuses in Parallel

Example: Two 25A fuse in parallel subjected to a 100,000 cycle square pulse with peak current of 100A for 5ms (Fig. 3)

Square pulse therefore,

$$I^2t = I_p^2t$$

$$i_1 = \frac{I}{1.53} = \frac{100}{1.53} = 65.35A \rightarrow i_1^2t$$

$$= (65.35)^2(0.005) = 21A^2sec$$

$$100,000 \text{ cycle derating} \rightarrow \frac{21A^2sec}{0.4} = 52.5A^2sec$$

$$\text{Temperature derating} \rightarrow \frac{52.5A^2sec}{0.85} = 61.7A^2sec$$

$$30\% \text{ safety margin} \rightarrow \frac{61.7A^2sec}{0.7} = 88.3A^2sec$$

Compare I_p^2t of pulse with I_f^2t of fuse at 5ms $\rightarrow I_f^2t \geq I_p^2t$

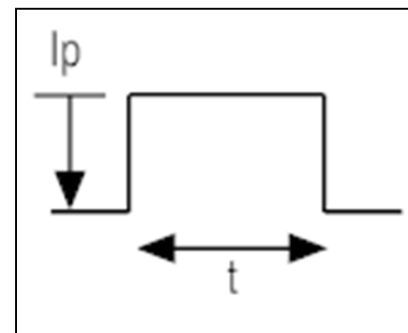


Figure 3

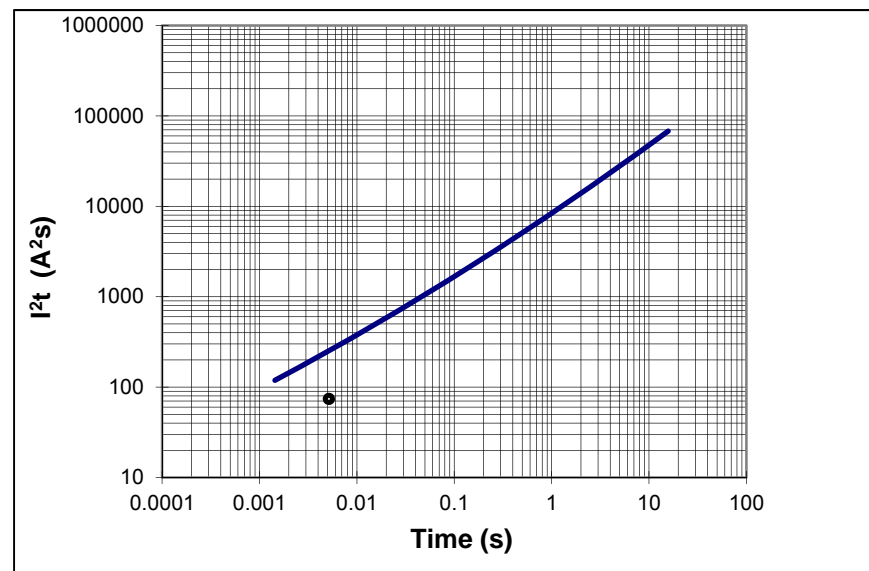


Figure 4

Conclusion

- ***Upper Limit:***
 - *UL or internal safety requirements*
- ***Lower Limit:***
 - *Steady-state requirement (20.5A)*
 - *Transient state (88A²sec)*