MOTOR SELECTION

Motor Selection

- It is recommended to ensure that the load inertia, as seen by the motor, is *no more than 10 times* the *motor inertia*.
- Use the velocity profile to find the *peak torque*.
- Any torque applied for a sufficiently long amount of time should be less than the *continuous operation torque* of the motor.
- If the torque changes quickly, find the *rms torque* and check that it does not exceed the continuous operation torque.
- Motors are damaged by excessive heat, when they reach a high enough temperature.
  - Higher torques are possible if the motors are cooled.

Load Inertia—Example

Consider a rack and pinion system in which the pinion radius is $\rho = 0.05\ m$, the mass of the rack is $m = 5\ kg$, and the motor drives the pinion through a gear reduction box of ratio $n = 20$. Find the load inertia reflected to the motor.

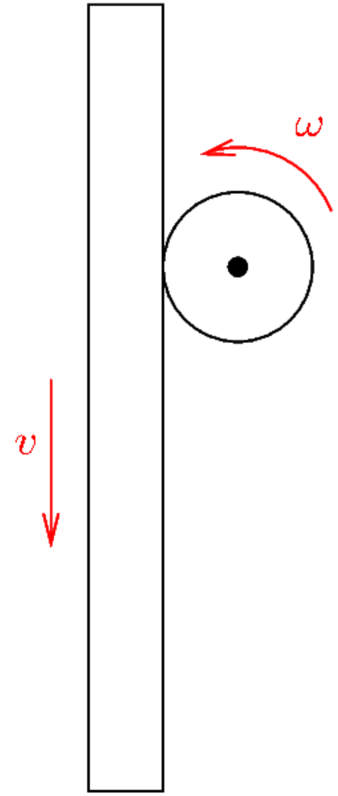
- *Suppose that a positive motor torque T_m accelerates the pinion.*
- *Since both the motor torque and mg accelerate the system, the power balance is:*

$$T_m \omega_m + mgv = (J_m \dot{\omega}_m)\omega_m + (m\dot{v})v$$

- *Note that J_m is the inertia of the motor.*
- *Since $v = \rho\omega$ and $\omega_m = n\omega$, the equation can be simplified to*

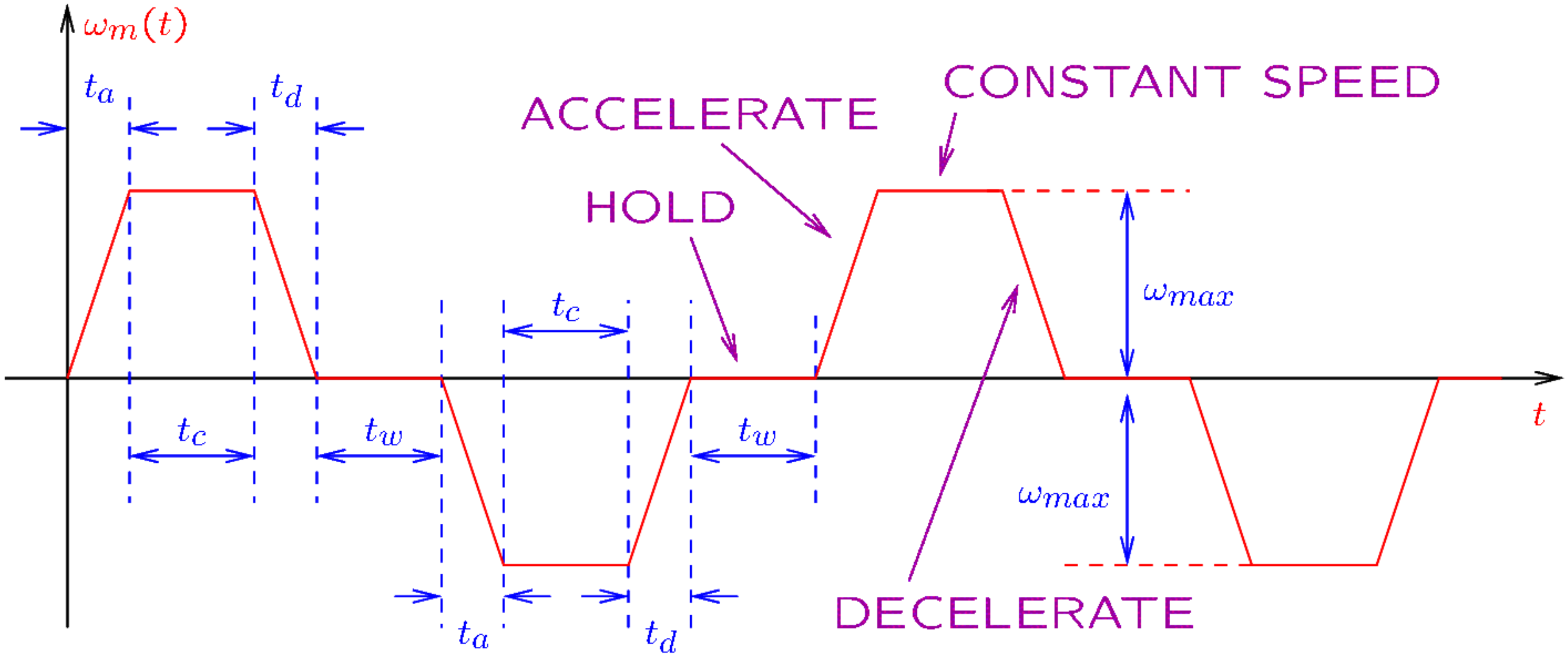
$$T_m + \frac{mg\rho}{n} = \left(J_m + \frac{m\rho^2}{n^2}\right)\dot{\omega}_m$$

- *The inertia reflected to the motor is $J_{L\to M} = \frac{m\rho^2}{n^2} = 31.25 \cdot 10^{-6}\ kgm^2$.*



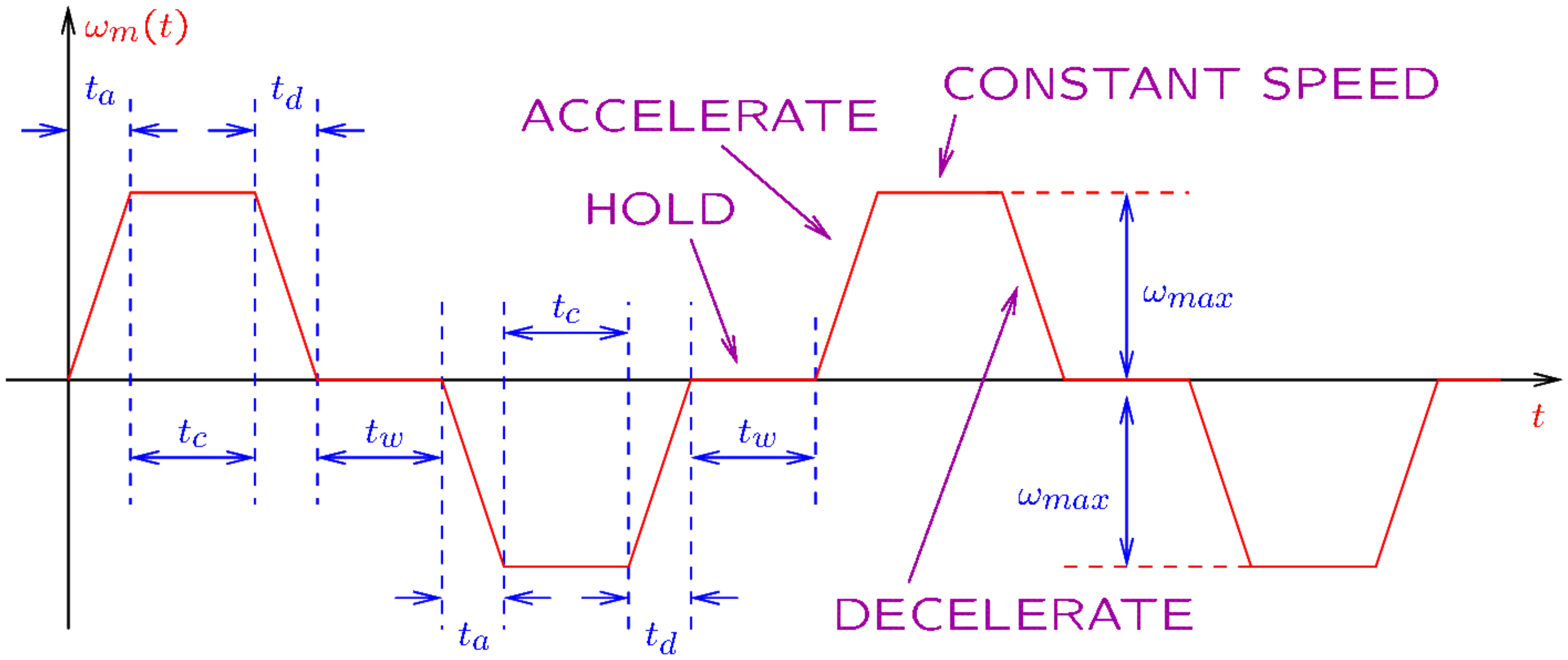
Velocity Profile

- Consider a manufacturing setting in which a motor has to perform again and again the same task.
- Over time, the velocity of the motor could look like this:



Velocity Profile

- Let t_a be the *acceleration time*, t_d the *deceleration time*, t_c the *constant speed time*, and t_w the *wait time*.
- The period (cycle length) in the figure is $2(t_a + t_c + t_d + t_w)$.
- When the motor accelerates, the acceleration is $\dot{\omega}_m = \omega_{max}/t_a$, and when it decelerates, $\dot{\omega}_m = -\omega_{max}/t_d$.
- Given the motor accelerations, we can find the *peak torque*.



Peak Torque—Example

Consider the rack and pinion system with the following specification: $J_m = 2 \cdot 10^{-4}\, kgm^2$, $v_{max} = 2\, m/s$, $t_a = t_d = 0.1\, s$, *and* $t_c = t_w = 0.4\, s$. *Find the peak torque.*

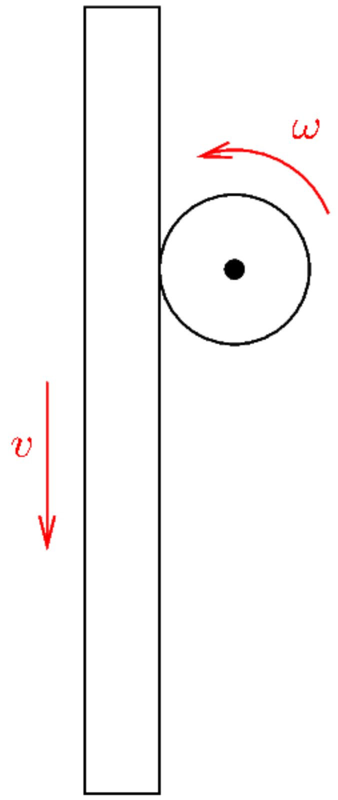
- *From* v_{max} *and* $\omega_m = v_m n/\rho$ *we find* $\omega_{max} = \frac{v_{max} n}{\rho} = 800\, rad/s$.
- *As derived earlier, the motor torque is*

$$T_m = -\frac{mg\rho}{n} + \left(J_m + \frac{m\rho^2}{n^2}\right)\dot{\omega}_m$$

- *The maximum motor accelerations are*

$$\dot{\omega}_{m,max} = \max\left(\frac{\omega_{max}}{t_a}, \frac{\omega_{max}}{t_d}\right) = 8000\, rad/s^2 \text{ and}$$

$$\dot{\omega}_{m,min} = \min\left(-\frac{\omega_{max}}{t_d}, -\frac{\omega_{max}}{t_a}\right) = -8000\, rad/s^2.$$



Peak Torque—Example

- *The peak torque will be the largest of the following:*

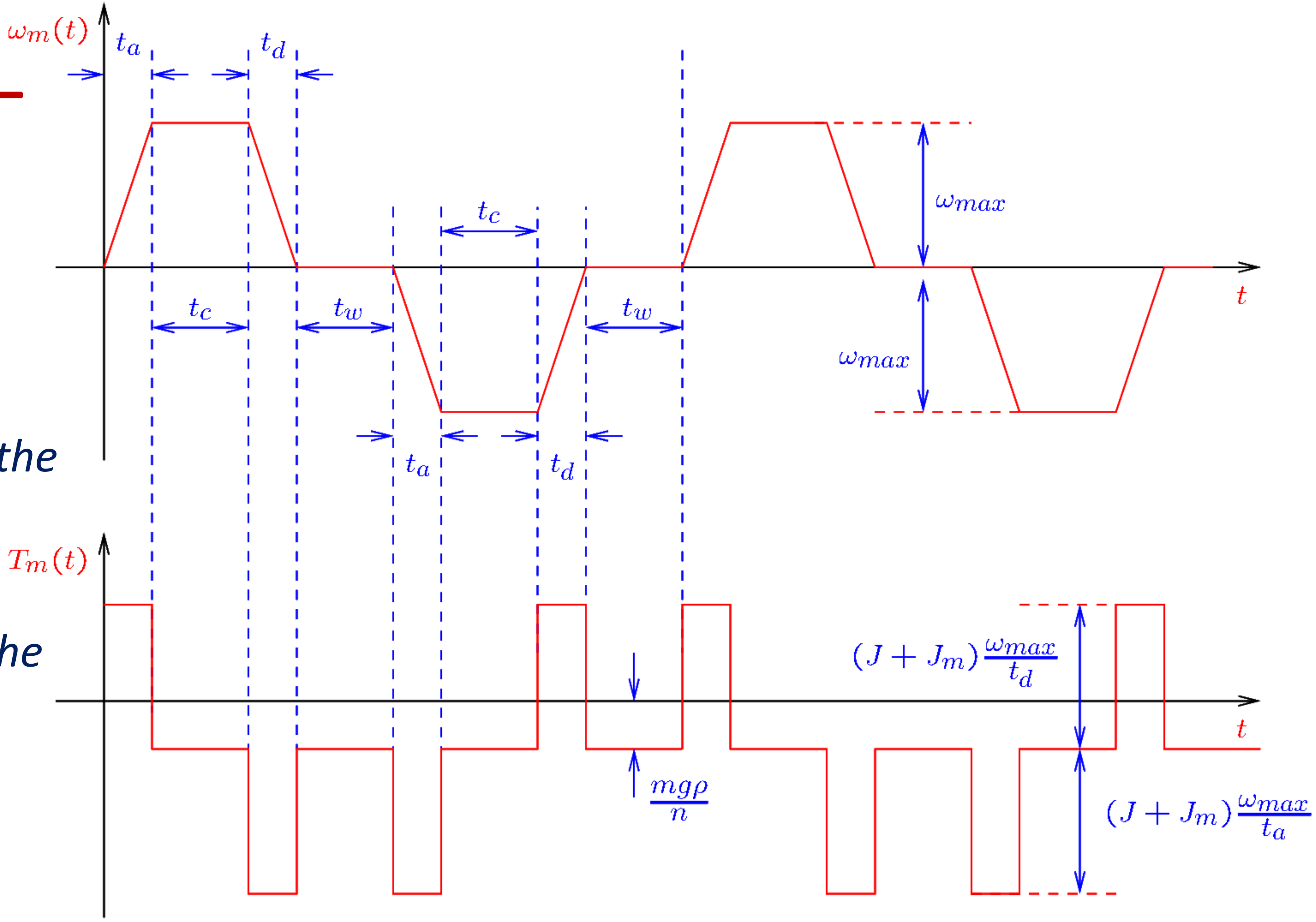
$$T_m = -\frac{mg\rho}{n} + \left(J_m + \frac{m\rho^2}{n^2}\right)\dot{\omega}_{m,max} = 1.72\ Nm$$

$$T_m = -\frac{mg\rho}{n} + \left(J_m + \frac{m\rho^2}{n^2}\right)\dot{\omega}_{m,min} = -1.97\ Nm$$

- *Thus, this example requires a motor capable of delivering a peak torque of* $1.97\ Nm$ *within a speed range of* $0 \ldots 800\ rad/s$.

Peak Torque—Example

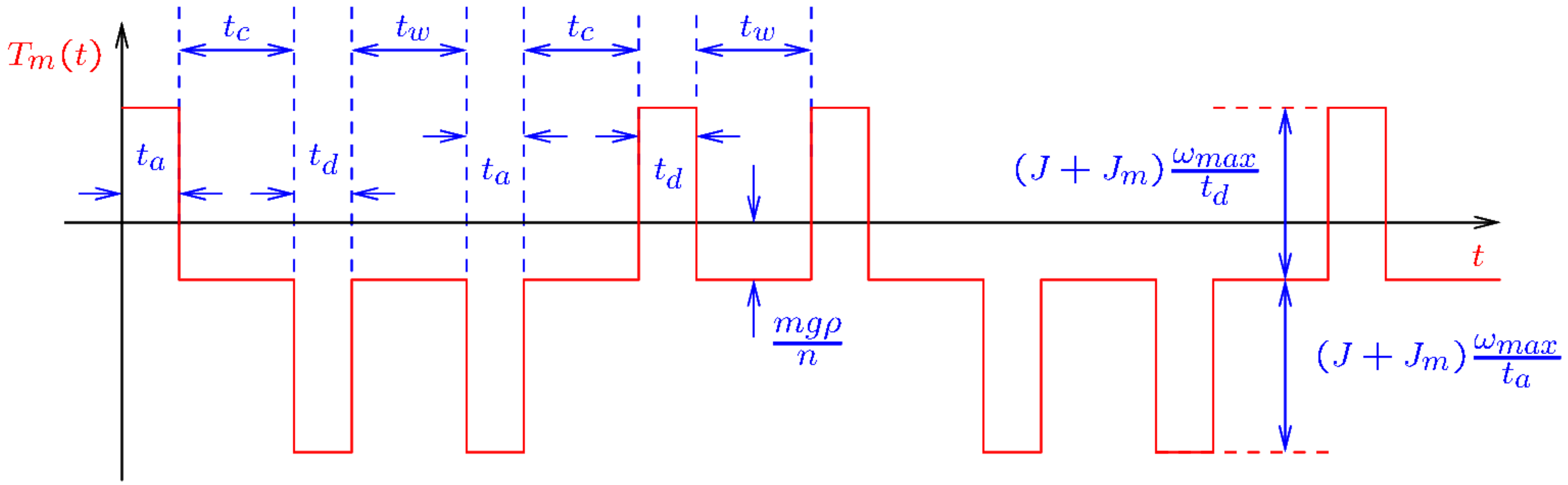
- *Let J be the load inertia reflected to the motor.*
- *Note the graph of the motor torque.*



RMS Torque

- The root mean square (rms) torque is the square root of the mean of the square of the torque.
- The rms torque should fit the continuous operation torque specification of a motor.

Example: Given the following torque graph, find the rms torque.

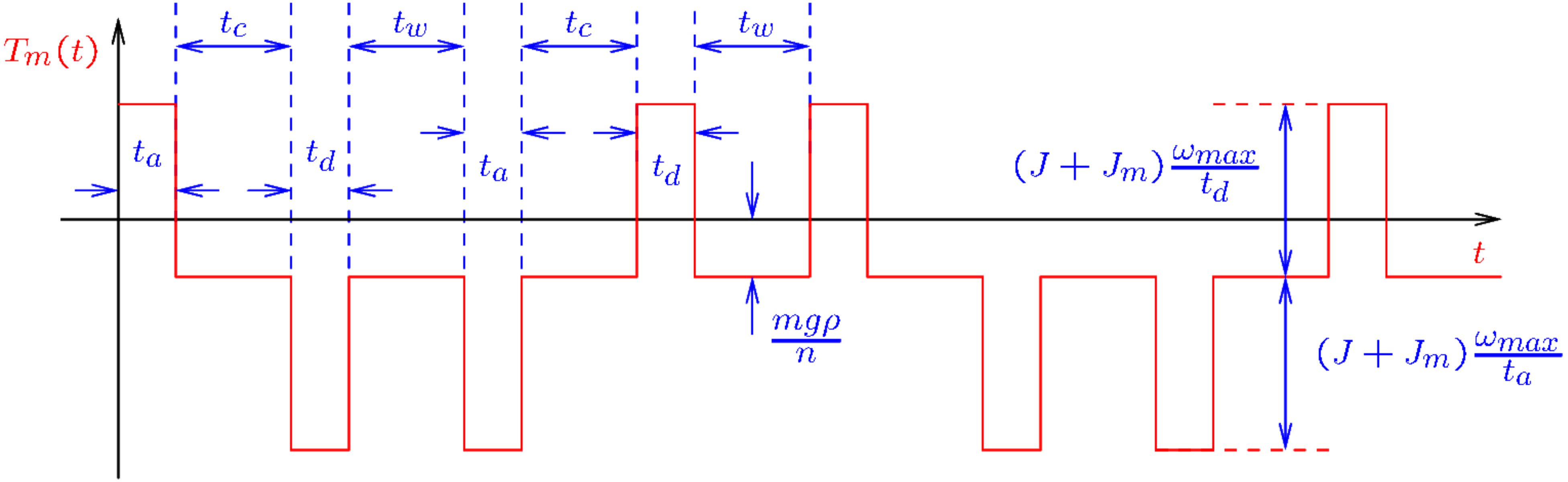


RMS Torque

Example: Given the following torque graph, find the rms torque. You may assume $t_d = t_a$.

- *Let* $T = (J + J_m)\omega_{max}/t_d$ *and* $T_0 = mg\rho/n$.
- *Let us consider an entire period (cycle).*
- *For each time interval, the squared torque is multiplied by the length of the time interval.*

$$T_{rms} = \sqrt{\frac{(T - T_0)^2 t_a + T_0^2 t_c + (T + T_0)^2 t_d + T_0^2 t_w + (T + T_0)^2 t_a + T_0^2 t_c + (T - T_0)^2 t_d + T_0^2 t_w}{t_a + t_c + t_d + t_w + t_a + t_c + t_d + t_w}}$$



Motor Selection

- It is recommended to ensure that the load inertia, as seen by the motor, is *no more than 10 times* the *motor inertia*.
  - *In our example,* $J_m = 2 \cdot 10^{-4}\ kgm^2$ *and* $J_{L \to M} = 31.25 \cdot 10^{-6}\ kgm^2$.
  - *Since* $J_{L \to M} \leq 10 J_m$*, this constraint is satisfied.*
- Use the velocity profile to find the *peak torque*.
- Any torque applied for a sufficiently long amount of time should be less than the *continuous operation torque* of the motor.
- If the torque changes quickly, find the *rms torque* and check that it does not exceed the continuous operation torque.

Motor Selection

- In a torque-speed motor specification, the area under the intermittent duty curve is a zone in which the motor may be operated briefly.
- The area under the continuous duty curve is a zone in which the motor may be continuously operated.
- The *peak torque* should be under the intermittent duty curve.
- The *rms torque* should be under the continuous duty curve.