ATTACHMENT A

Torque Calculations, Parameter Comparisons, and Chart Summaries 1 and 2

Torque Calculations and Voltage and Current Conversions

Throughout Torque = τ $K_{e\phi\phi p} = \frac{e_{B\phi\phi p}}{\omega}$ $K_{e\phi\phi rms} = \frac{e_{B\phi\phi rms}}{\omega}$

$K_{Tp} = \frac{\tau}{I_{\phi\phi p}}$ $K_{Trms} = \frac{\tau}{I_{\phi\phi rms}}$

MOTOR / DRIVE

Square / Square [Refer to (29)]

$\tau_{QQ} = K_{e\phi\phi p} \cdot I_{\phi\phi p}$ (A1)

$\tau_{QQ} = \sqrt{3} \cdot \sqrt{\frac{9}{10}} \cdot K_{e\phi\phi rms} \cdot I_{\phi\phi rms}$ (A2)

$e_{B\phi\phi rms} = \frac{\sqrt{5}}{3} \cdot e_{B\phi\phi p}$ (A3)

$K_{Tp} = K_{e\phi\phi p}$ (A4)

$I_{\phi\phi rms} = \sqrt{\frac{2}{3}} \cdot I_{\phi\phi p}$ (A5)

$K_{Trms} = \sqrt{\frac{3}{2}} \cdot K_{\phi\phi p}$ (A6)

Sine / Sine [Refer to (26)]

$\tau_{SS} = \frac{\sqrt{3}}{2} K_{e\phi\phi p} \cdot I_{\phi\phi p}$ (A7)

$\tau_{SS} = \sqrt{3} \cdot K_{e\phi\phi rms} \cdot I_{\phi\phi rms}$ (A8)

$e_{B\phi\phi rms} = \frac{e_{B\phi\phi p}}{\sqrt{2}}$ (A9)

$K_{Tp} = \frac{\sqrt{3}}{2} \cdot K_{e\phi\phi p}$ (A10)

$I_{\phi\phi rms} = \frac{I_{\phi\phi p}}{\sqrt{2}}$ (A11)

$K_{Trms} = \sqrt{\frac{3}{2}} \cdot K_{\phi\phi p}$ (A12)

Sine / Square [Refer to (33)]

$\tau_{SQ} = \frac{3}{\pi} K_{e\phi\phi p} \cdot I_{\phi\phi p}$ (A13)

$\tau_{SQ} = \frac{3}{\pi} \sqrt{3} \cdot K_{e\phi\phi rms} \cdot I_{\phi\phi rms}$ (A14)

$e_{B\phi\phi rms} = \frac{e_{B\phi\phi p}}{\sqrt{2}}$ (A15)

$K_{Tp} = \frac{3}{\pi} \cdot K_{e\phi\phi p}$ (A16)

$I_{\phi\phi rms} = \sqrt{\frac{2}{3}} \cdot I_{\phi\phi p}$ (A17)

$K_{Trms} = \frac{3}{\pi} \sqrt{\frac{3}{2}} \cdot K_{\phi\phi p}$ (A18)

Square / Sine [Refer to (37)]

$\tau_{QS} = \left(\frac{3}{\pi}\right)^2 \cdot K_{e\phi\phi p} \cdot I_{\phi\phi p}$ (A19)

$\tau_{QS} = \sqrt{3} K_{e\phi\phi rms} \cdot I_{\phi\phi rms}$ (A20)

$e_{B\phi\phi rms} = \left(\frac{3}{\pi}\right)^2 \cdot \sqrt{\frac{2}{3}} \cdot e_{B\phi\phi p}$ (A21)

$K_{Tp} = \left(\frac{3}{\pi}\right)^2 \cdot K_{e\phi\phi p}$ (A22)

$I_{\phi\phi rms} = \frac{I_{\phi\phi p}}{\sqrt{2}}$ (A23)

$K_{Trms} = \left(\frac{3}{\pi}\right)^2 \cdot \sqrt{2} \cdot K_{e\phi\phi p}$ (A24)

Comparison of Motor / Drive = Sine / Sine with Sine / Square

Relationships

When RMS currents are equal --

$$\frac{I_{\phi\phi pSS}}{\sqrt{2}} = \sqrt{\frac{2}{3}} \cdot I_{\phi\phi pSQ} \qquad [\ (A11) = (A17)\ ]$$

Then

$$I_{\phi\phi pSS} = \frac{2}{\sqrt{3}} \cdot I_{\phi\phi pSQ} \qquad (A25) \qquad \text{Relating peak currents.}$$

Resistor power loss --

$$P_{RSS} = \frac{3}{2} \cdot I_{\phi\phi rmsSS}{}^{2} \cdot R_{\phi\phi} = \frac{3}{2} \frac{I_{\phi\phi pSS}{}^{2}}{2} \cdot R_{\phi\phi} \qquad [\text{Refer to (27)}]$$

$$P_{RSQ} = I_{\phi\phi pSQ}{}^{2} \cdot R_{\phi\phi} \qquad [\text{Refer to (34)}]$$

Equating resistor power loss --

$$I_{\phi\phi pSS} = I_{\phi\phi pSQ} \cdot \sqrt{\frac{4}{3}} = I_{\phi\phi pSQ} \cdot \frac{2}{\sqrt{3}}$$

Let $K_{e\phi\phi pSS} = K_{e\phi\phi pSQ} = K_{e\phi\phi p}$

$$\frac{K_{TpSS}}{K_{e\phi\phi p}} = \frac{\sqrt{3}}{2} \quad \text{From (A10)} \qquad \frac{K_{TpSQ}}{K_{e\phi\phi p}} = \frac{3}{\pi} \quad \text{From (A16)}$$

$$\frac{K_{TpSQ}}{K_{TpSS}} = \frac{2 \cdot \sqrt{3}}{\pi} \qquad (A26) \qquad \frac{2 \cdot \sqrt{3}}{\pi} = 1.1027$$

$$K_{TrmsSS} = \sqrt{\frac{3}{2}} \cdot K_{e\phi\phi p} \quad \text{From (A12)} \qquad K_{TrmsSQ} = \frac{3}{\pi} \cdot \sqrt{\frac{3}{2}} \cdot K_{e\phi\phi p} \quad \text{From (A18)}$$

$$\frac{K_{TrmsSQ}}{K_{TrmsSS}} = \frac{3}{\pi} \qquad (A27) \qquad \frac{3}{\pi} = 0.95493$$

Torque generated is less when a sinewave motor is driven with a squarewave drive instead of a sinewave drive; the rms currents being equal.

Comparison of Motor / Drive = Square / Square with Square / Sine

When rms currents are equal - -

$$\frac{I_{\phi\phi pQS}}{\sqrt{2}} = \sqrt{\frac{2}{3}} \cdot I_{\phi\phi pQQ} \qquad [\ (A23) = (A5)\ ]$$

Then

$$I_{\phi\phi pQS} = \frac{2}{\sqrt{3}} \cdot I_{\phi\phi pQQ} \qquad (A28) \qquad \text{Relating peak currents.}$$

$$\frac{K_{TpQQ}}{K_{e\phi\phi p}} = 1 \qquad \text{From (A4)} \qquad \frac{K_{TpQS}}{K_{e\phi\phi p}} = \left(\frac{3}{\pi}\right)^2 \qquad \text{From (A22)}$$

$$\frac{K_{TpQS}}{K_{TpQQ}} = \left(\frac{3}{\pi}\right)^2 \qquad (A29) \qquad \left(\frac{3}{\pi}\right)^2 = 0.9119$$

$$K_{TrmsQQ} = \sqrt{\frac{3}{2}} \cdot K_{e\phi\phi p} \qquad \text{From (A6)} \qquad K_{TrmsQS} = \left(\frac{3}{\pi}\right)^2 \cdot \sqrt{2} \cdot K_{e\phi\phi p} \qquad \text{From (A24)}$$

$$\frac{K_{TrmsQS}}{K_{TrmsQQ}} = \frac{6}{\pi^2} \cdot \sqrt{3} \qquad (A30) \qquad \frac{6}{\pi^2} \cdot \sqrt{3} = 1.05296$$

Torque generated is increased when a squarewave motor is driven with a sinewave drive instead of a squarewave drive; the rms currents being equal.

CHART 1				PARAMETERS					
Motor / Drive	**Column 1**		**Column 2**		**Column 3**		**Column 4**		**Column 5**
	$\frac{K_{Tp}}{K_{e\phi\phi p}}$		$\frac{K_{Trms}}{K_{Tp}}$		$\frac{K_{e\phi\phi rms}}{K_{Trms}}$		$\frac{K_{e\phi\phi rms}}{K_{e\phi\phi p}}$		KTp*Keϕϕp
Square / Square	1		$\sqrt{\frac{3}{2}}$		$\sqrt{\frac{10}{9}}\cdot\frac{1}{\sqrt{3}}$		$\frac{\sqrt{5}}{3}$		$\frac{2}{3}\cdot K_{Trms}^{2}$
Sine / Sine	$\frac{\sqrt{3}}{2}$		$\sqrt{2}$		$\frac{1}{\sqrt{3}}$		$\frac{1}{\sqrt{2}}$		$\frac{K_{Trms}^{2}}{\sqrt{3}}$
Sine / Square	$\frac{3}{\pi}$		$\sqrt{\frac{3}{2}}$		$\frac{\pi}{3}\cdot\frac{1}{\sqrt{3}}$		$\frac{1}{\sqrt{2}}$		$\frac{\pi}{3}\cdot\frac{2}{3}K_{Trms}^{2}$
Square / Sine	$\left(\frac{3}{\pi}\right)^{2}$		$\sqrt{2}$		$\frac{1}{\sqrt{3}}$		$\left(\frac{3}{\pi}\right)^{2}\cdot\sqrt{\frac{2}{3}}$		$\left(\frac{\pi}{3}\right)^{2}\cdot\frac{K_{Trms}^{2}}{2}$

CHART 2 — **FIGURES OF MERIT**

Motor / Drive	Column 6	Column 7	Column 8	Column 9	Column 10
	P_R	K_M	R_m	τ_m	$\frac{K_{Trms} \cdot K_{e\phi\phi rms}}{K_{Tp} \cdot K_{e\phi\phi p}}$
Square / Square	* $R_{\phi\phi} \cdot \left(\frac{\tau}{K_{TP}} \right)^2$	** $\frac{K_{Tp}}{\sqrt{R_{\phi\phi}}}$	$\frac{R_{\phi\phi}}{K_{Tp} \cdot K_{e\phi\phi p}}$	$\frac{R_{\phi\phi p} \cdot J}{K_{Tp} \cdot K_{e\phi\phi p}}$	$\sqrt{\frac{5}{6}}$
Sine / Sine	$\frac{3}{2} R_{\phi\phi} \cdot \left(\frac{\tau}{K_{Trms}} \right)^2$	$\sqrt{\frac{2}{3}} \cdot \frac{K_{Trms}}{\sqrt{R_{\phi\phi}}}$	$\frac{\sqrt{3}}{2} \frac{R_{\phi\phi}}{K_{Tp} \cdot K_{e\phi\phi p}}$	$\frac{\sqrt{3}}{2} \cdot \frac{R_{\phi\phi} \cdot J}{K_{Tp} \cdot K_{e\phi\phi p}}$	1
Sine / Square	* $R_{\phi\phi} \cdot \left(\frac{\tau}{K_{TP}} \right)^2$	** $\frac{K_{Tp}}{\sqrt{R_{\phi\phi}}}$	$\frac{R_{\phi\phi}}{K_{Tp} \cdot K_{e\phi\phi p}}$	$\frac{R_{\phi\phi p} \cdot J}{K_{Tp} \cdot K_{e\phi\phi p}}$	$\frac{\sqrt{3}}{2}$
Square / Sine	$\frac{3}{2} R_{\phi\phi} \cdot \left(\frac{\tau}{K_{Trms}} \right)^2$	$\sqrt{\frac{2}{3}} \cdot \frac{K_{Trms}}{\sqrt{R_{\phi\phi}}}$	$\frac{\sqrt{3}}{2} \frac{R_{\phi\phi}}{K_{Tp} \cdot K_{e\phi\phi p}}$	$\frac{\sqrt{3}}{2} \cdot \frac{R_{\phi\phi} \cdot J}{K_{Tp} \cdot K_{e\phi\phi p}}$	$\left(\frac{3}{\pi} \right)^2 \cdot \frac{2}{\sqrt{3}}$
	ALSO * = $\frac{3}{2} \cdot R_{\phi\phi} \cdot \left(\frac{\tau}{K_{Trms}} \right)^2$	**ALSO** ** = $\sqrt{\frac{2}{3}} \cdot \frac{K_{Trms}}{\sqrt{R_{\phi\phi}}}$			