

Equation Sheet

Transformation to discrete systems:

$$\text{Forward difference } s = \frac{z-1}{T}$$

$$\text{Backward difference } s = \frac{z-1}{Tz}$$

$$\text{Bilinear transformation } s = \frac{2}{T} \frac{z-1}{z+1}$$

$$\text{Final Value } y_{ss} = \lim_{z \rightarrow 1} \left[(1-z^{-1})Y(z) \right]$$

G & M codes

G01	Linear interpolation
G02	Circular interpolation, CW
G03	Circular interpolation, CCW
G06	Spline execution command
G17	XY plane selection
G40	Cancellation of tool radius compensation
G41	Tool radius compensation to the left of profile
G42	Tool radius compensation to the right of profile
G48	Beginning of spline curve definition
G70	Data input in inches
G71	Data input in metrics
G77	Unconditional call or jump with return
G79	Conditional or unconditional jump to a sequence without return
G90	Absolute dimension programming
G91	Relative dimension programming
M02	End of program
M03	Clockwise spindle rotation
M04	Anti-clockwise spindle rotation
M05	Spindle stop
M06	Tool change

APT Language

Point	POINT
Line	LINE
Plane	PLANE
Circle	CIRCLE
Pattern	PATERN
Cylinder	CYLNDR

FROM/
 GOTO/
 GODLTA/
 GO/TO
 GO/ON
 GO/PAST
 GOLFT/
 GORGT/
 GOUP/
 GODOWN/
 GOFWD/
 GOBACK/

GO/ $\left\{ \begin{array}{c} \text{TO} \\ \text{PAST} \\ \text{ON} \end{array} \right\}$ drive surface, $\left\{ \begin{array}{c} \text{TO} \\ \text{PAST} \\ \text{ON} \end{array} \right\}$ part surface, $\left\{ \begin{array}{c} \text{TO} \\ \text{PAST} \\ \text{ON} \end{array} \right\}$ check surface

TABLE 8.1 Laplace Transforms and z-transforms of Simple Discrete Time Functions

$F(s)$ is the Laplace transform of $f(t)$, and $F(z)$ is the z-transform of $f(kT)$. Note: $f(t) = 0$ for $t = 0$.

Number	$\mathcal{F}(s)$	$f(kT)$	$F(z)$
1		$1, k = 0; 0, k \neq 0$	1
2		$1, k = k_0; 0, k \neq k_0$	z^{-k_0}
3	$\frac{1}{s}$	$1(kT)$	$\frac{z}{z-1}$
4	$\frac{1}{s^2}$	kT	$\frac{Tz}{(z-1)^2}$
5	$\frac{1}{s^3}$	$\frac{1}{2!}(kT)^2$	$\frac{T^2}{2} \left[\frac{z(z+1)}{(z-1)^3} \right]$
6	$\frac{1}{s^4}$	$\frac{1}{3!}(kT)^3$	$\frac{T^3}{6} \left[\frac{z(z^2+4z+1)}{(z-1)^4} \right]$
7	$\frac{1}{s^m}$	$\lim_{a \rightarrow 0} \frac{(-1)^{m-1}}{(m-1)!} \left(\frac{\partial^{m-1}}{\partial a^{m-1}} e^{-akT} \right)$	$\lim_{a \rightarrow 0} \frac{(-1)^{m-1}}{(m-1)!} \left(\frac{\partial^{m-1}}{\partial a^{m-1}} \frac{z}{z-e^{-aT}} \right)$
8	$\frac{1}{s+a}$	e^{-akT}	$\frac{z}{z-e^{-aT}}$
9	$\frac{1}{(s+a)^2}$	kTe^{-akT}	$\frac{Tze^{-aT}}{(z-e^{-aT})^2}$
10	$\frac{1}{(s+a)^3}$	$\frac{1}{2}(kT)^2 e^{-akT}$	$\frac{T^2}{2} e^{-aT} z \frac{(z+e^{-aT})}{(z-e^{-aT})^3}$
11	$\frac{1}{(s+a)^m}$	$\frac{(-1)^{m-1}}{(m-1)!} \left(\frac{\partial^{m-1}}{\partial a^{m-1}} e^{-akT} \right)$	$\frac{(-1)^{m-1}}{(m-1)!} \left(\frac{\partial^{m-1}}{\partial a^{m-1}} \frac{z}{z-e^{-aT}} \right)$
12	$\frac{a}{s(s+a)}$	$1 - e^{-akT}$	$\frac{z(1-e^{-aT})}{(z-1)(z-e^{-aT})}$
13	$\frac{a}{s^2(s+a)}$	$\frac{1}{a}(akT - 1 + e^{-akT})$	$\frac{z[(aT-1+e^{-aT})z + (1-e^{-aT}-aTe^{-aT})]}{a(z-1)^2(z-e^{-aT})}$
14	$\frac{b-a}{(s+a)(s+b)}$	$e^{-akT} - e^{-bkT}$	$\frac{(e^{-aT} - e^{-bT})z}{(z-e^{-aT})(z-e^{-bT})}$
15	$\frac{s}{(s+a)^2}$	$(1-akT)e^{-akT}$	$\frac{z[z - e^{-aT}(1+aT)]}{(z-e^{-aT})^2}$
16	$\frac{a^2}{s(s+a)^2}$	$1 - e^{-akT}(1+akT)$	$\frac{z[z(1-e^{-aT}-aTe^{-aT}) + e^{-2aT} - e^{-aT} + aTe^{-aT}]}{(z-1)(z-e^{-aT})^2}$
17	$\frac{(b-a)s}{(s+a)(s+b)}$	$be^{-bkT} - ae^{-akT}$	$\frac{z[z(b-a) - (be^{-aT} - ae^{-bT})]}{(z-e^{-aT})(z-e^{-bT})}$
18	$\frac{a}{s^2+a^2}$	$\sin akT$	$\frac{z \sin aT}{z^2 - (2 \cos aT)z + 1}$
19	$\frac{s}{s^2+a^2}$	$\cos akT$	$\frac{z(z - \cos aT)}{z^2 - (2 \cos aT)z + 1}$
20	$\frac{s+a}{(s+a)^2+b^2}$	$e^{-akT} \cos bkT$	$\frac{z(z - e^{-aT} \cos bT)}{z^2 - 2e^{-aT}(\cos bT)z + e^{-2aT}}$
21	$\frac{b}{(s+a)^2+b^2}$	$e^{-akT} \sin bkT$	$\frac{ze^{-aT} \sin bT}{z^2 - 2e^{-aT}(\cos bT)z + e^{-2aT}}$
22	$\frac{a^2+b^2}{s[(s+a)^2+b^2]}$	$1 - e^{-akT} \left(\cos bkT + \frac{a}{b} \sin bkT \right)$	$\frac{z(Az+B)}{(z-1)[z^2 - 2e^{-aT}(\cos bT)z + e^{-2aT}]}$ $A = 1 - e^{-aT} \cos bT - \frac{a}{b} e^{-aT} \sin bT$ $B = e^{-2aT} + \frac{a}{b} e^{-aT} \sin bT - e^{-aT} \cos bT$