Appendix A: List of Symbols

$\%OS$	Percent overshoot
A	Ampere—unit of electrical current
$\mathbf{A}$	System matrix for state-space representation
a_m	Motor time constant
B	Mechanical rotational coefficient of viscous friction in N-m-s/rad
$\mathbf{B}$	Input matrix for state-space representation
C	Electrical capacitance in farads
$\mathbf{C}$	Output matrix for state-space representation
$C(s)$	Laplace transform of the output of a system
$c(t)$	Output of a system
$\mathbf{C_M}$	Controllability matrix
D	Mechanical rotational coefficient of viscous friction in N-m-s/rad
$\mathbf{D}$	Feedforward matrix for state-space representation
D_a	Motor armature coefficient of viscous damping in N-m-s/rad
D_m	Total coefficient of viscous friction at the armature of a motor, including armature coefficient of viscous friction and reflected load coefficient of viscous friction in N-m-s/rad
E	Energy
$E(s)$	Laplace transform of the error
$e(t)$	Error; electrical voltage
$E_a(s)$	Laplace transform of the motor armature input voltage; Laplace transform of the actuating signal
$e_a(t)$	Motor armature input voltage; actuating signal
F	Farad—unit of electrical capacitance
$F(s)$	Laplace transform of $f(t)$
$f(t)$	Mechanical force in newtons; general time function
f_v	Mechanical translational coefficient of viscous friction
g	Acceleration due to gravity
G	Electrical conductance in mhos
$G(s)$	Forward-path transfer function
$G_c(s)$	Compensator transfer function
$G_c(z)$	Sampled transfer function for a compensator
G_M	Gain margin
$G_p(z)$	Sampled transfer function for a plant

H	Henry—unit of electrical inductance
$H(s)$	Feedback-path transfer function
I	Identity matrix
$i(t)$	Electrical current in amperes
J	Moment of inertia in kg-m^2
J_a	Motor armature moment of inertia in kg-m^2
J_m	Total moment of inertia at the armature of a motor, including armature moment of inertia and reflected load moment of inertia in kg-m^2
K	Controller gain matrix
K	Mechanical translational spring constant in N/m or rotational spring constant in N-m/rad; amplifier gain; residue
k	Controller feedback gain; running index
K_a	Acceleration constant
K_b	Back emf constant in V/rad/s
K_f	Feedback gain
kg	*Kilogram = newton seconds^2/meter—unit of mass*
kg-m^2	Kilogram meters^2 = newton-meters seconds^2/radian—unit of moment of inertia
K_m	Motor gain
K_p	Position constant
K_t	Motor torque constant relating developed torque to armature current in N-m/A
K_v	Velocity constant
L	Electrical inductance in henries
L	Observer gain matrix
l	Observer feedback gain
M	Mass in kilograms; slope of the root locus asymptotes
m	Meter—unit of mechanical translational displacement
$M(\omega)$	Magnitude of a sinusoidal response
m/s	Meters/second—unit of mechanical translational velocity
M_P	Peak magnitude of the sinusoidal magnitude response
N	Newton—unit of mechanical translational force in kilogram meters/second^2
N-s/m	Newton-seconds/meter—unit of mechanical translational coefficient of viscous friction
n	System type
N/m	Newton/meter—unit of mechanical translational spring constant
N-m	Newton-meter—unit of mechanical torque
N-m-s/rad	Newton-meter-seconds/radian—unit of mechanical rotational coefficient of *viscous friction*
N-m/A	Newton-meter/ampere—unit of motor torque constant
N-m/rad	Newton-meter/radian—unit of mechanical rotational spring constant
$\mathbf{O_M}$	Observability matrix
P	Similarity transformation matrix
p_c	Compensator pole
Q	Coulomb—unit of electrical charge
$q(t)$	Electrical charge in coulombs

R	Electrical resistance in ohms
$R(s)$	Laplace transform of the input to a system
r	Nonlinear electrical resistance
$r(t)$	Input to a system
R_a	Motor armature resistance in ohms
rad	Radian—unit of angular displacement
rad/s	Radian/second—unit of angular velocity
s	Second—unit of time
s	Complex variable for the Laplace transform
$S_{F:P}$	Sensitivity of F to a fractional change in P
T	Time constant; sampling interval for digital signals
$T(s)$	Closed-loop transfer function; Laplace transform of mechanical torque
$T(t)$	Mechanical torque in N-m
$T_m(t)$	Torque at the armature developed by a motor in N-m
$T_m(s)$	Laplace transform of the torque at the armature developed by a motor
T_p	Peak time in seconds
T_r	Rise time in seconds
T_s	Settling time in seconds
T_w	Pulse width in seconds
$\mathbf{u}$	Input or control vector for state-space representation
u	Input control signal for state-space representation
$u(t)$	Unit step input
V-s/rad	Volt-seconds/radian—unit of motor back emf constant
$v(t)$	Mechanical translation velocity in m/s; electrical voltage
$v_b(t)$	Motor back emf in volts
$v_e(t)$	Error voltage
$v_p(t)$	Power amplifier input in volts
$\mathbf{x}$	State vector for state-space representation
$x(t)$	Mechanical translation displacement in meters; a state variable
$\dot{x}$	Time derivative of a state variable
$\dot{\mathbf{x}}$	Time derivative of the state vector
$\mathbf{y}$	Output vector for state-space representation
$y(t)$	Output scalar for state-space representation
z	Complex variable for the z-transform
z_c	Compensator zero
α	Pole-scaling factor for a lag compensator, where $\alpha > 1$; angle of attack
β	Pole-scaling factor for a lead compensator, where $\beta < 1$
γ	Pole-scaling factor for a lag-lead compensator, where $\gamma > 1$
δ	Thrust angle
ζ	Damping ratio
θ	Angle of a vector with the positive extension of the real axis
$\theta(t)$	Angular displacement
θ_a	Angle of a root locus asymptote with the positive extension of the real axis

θ_c	Angular contribution of a compensator on the s-plane
$\theta_m(t)$	Angular displacement of the armature of a motor
λ	Eigenvalue of a square matrix
σ	Real part of the Laplace transform variable, s
σ_a	Real-axis intercept of the root locus asymptotes
Φ_M	Phase margin
$\Phi(t)$	State transition matrix
ϕ	Sinusoidal phase angle; body angle
ϕ_c	Sinusoidal phase angle of a compensator
ϕ_{max}	Maximum sinusoidal phase angle
Ω	Ohm—unit of electrical resistance
$\mho$	Mho—unit of electrical conductance
ω	Imaginary part of the Laplace transform variable, s
$\omega(t)$	Angular velocity in rad/s
ω_{BW}	Bandwidth in rad/s
ω_d	Damped frequency of oscillation in rad/s
ω_{Φ_M}	Phase-margin frequency in radians
ω_{G_M}	Gain-margin frequency in radians
ω_n	Natural frequency in rad/s
ω_p	Peak-magnitude frequency of the magnitude frequency response in rad/s