• For completely controllable and observable systems, the determinant of the matrix on the left side of (7.10) is identical to the numerator polynomial \( c \cdot \text{Adj}(sI - A) \cdot b \) of the system's transfer function \( \Sigma(s) \).

Figure 7.5  
Minus missing in graph

Equation (8.37)

\[
\angle \Sigma(0) = \angle \left\{ \frac{b_0}{a_0} \right\} + \angle \{(-j)^k \cdot \infty\}
\]

The values \( \gamma \) and \( \phi \) can be used to quantify the robustness of the control system described by \( L(s) \) to pure-gain or pure-phase modeling errors. The underlying assumption is that the “true” loop gain may be written as

\[
L_t(s) = e^{-\alpha \cdot s/\omega_n} \cdot k \cdot L(s)
\]

with \( L(s) \) being the nominal loop gain that yields an asymptotically stable nominal closed loop \( T(s) = L(s)/(1 + L(s)) \). If only a phase error is present \((k = 1)\), the “true” closed loop \( T_t(s) = L_t(s)/(1 + L_t(s)) \) remains stable as long as \( \alpha < \phi \). For the case of a pure-gain error \((\alpha = 0)\), stability is preserved as long as \( k < \gamma \). Of course, if both error sources are present simultaneously or if more general model uncertainties must be expected, the limits \( \{\gamma, \phi\} \) are no longer meaningful.
This illustration is missing in the 3rd Edition. Since it clarifies some important points it will be added in forthcoming editions (as a Quick Check at the end of Section 7.4.1).

**Figure xx.x.** Connections between the location of the poles and the time-domain behavior (impulse response) of a standard second-order system.
The definition of $\mu_{\text{min}, r}$ is illustrated in Figure 12.1. According to the robust Nyquist theorem introduced in Section 9.4.2, the set $S (8.46)$, parametrized by $\{L(s), W_2(s)\}$, will include (at least) one element that yields an unstable system after the loop is closed with unity feedback if the following additional disturbance is present

$$\tilde{L}_t(s) = L_t(s) + z, \quad z \in \mathbb{C}, \quad |z| > \mu_{\text{min}, r}, \quad \angle z \in [-\pi, +\pi] \quad (12.1)$$

**Quick Check 12.2.1:** Give an algebraic definition of $\mu_{\text{min}, r}$. 

![Diagram showing the Nyquist plot with $-1$, $\mu_{\text{min}, r}$, $L(j\omega)$, and $L_t(j\omega)$ labeled.]
Solution to Quick Check 4.4.4

The linear system with

\[
A_2 = \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix}
\]

(“system 2” on the right side of Figure C.4) also has two eigenvalues \( \lambda_{1,2} = 0 \), but it is diagonal. Consequently, this system is stable, as an analysis of the following differential equations shows

\[
\frac{dx_1(t)}{dt} = u(t)
\]

\[
\frac{dx_2(t)}{dt} = u(t)
\]

Remark: several orthographic and grammar errors have been found as well. Since they do not cause any substantial confusion they are not reported here.