Note: The relay with or without hysteresis (two-level switch) can be treated simply by the method of Sec. 9.1. This table gives sampled describing functions for the relay with dead zone and the linear, lead pulse-width modulator.
Figure F.1 Sampled describing function for the relay with dead zone nonlinearity (cf. Sec. 9.2).

\[ N(A,\phi) = \text{sampled describing function} \]
\[ \quad = \text{amplitude and phase relation between the sinusoid } x(t) \text{ and the fundamental harmonic component of } y^*(t) \]

\[ N^*(A,\phi) = z\text{-transform describing function} \]
\[ \quad = \left. \frac{z \text{ transform of } y^*(t)}{z \text{ transform of } x(t)} \right|_{z = \exp(j\omega_nT/n)} \]

\[ N^*(A,\phi) = T_N N(A,\phi) \]

This figure, in 7 parts, consists of plots of extreme values of \(-1/N(A,\phi)\) for \(n = 2, 3, \ldots, 8\). Only the unbiased output modes are included as they are the only modes of interest in the case of an unbiased input \(x(t)\) (see Sec. 9.2).
Figure F-1a  \( T = 2T \)
Figure F-1b  $T = 3T_s$
Figure F-1c  $T = 4T_1$.
Figure F-1d \[ T = 5T_s \]
Figure F-1e  \( T = 6T_s \)
Figure F-1f  \( T = 7T_s \)
\[ \frac{D}{\delta T_i} \left[ -\frac{1}{N} \right] \]

\[ \left\langle -\frac{1}{N \cos \theta} \right\rangle \]

Figure F-1g  \( T = 8T_i \)
The operation of the PWM is defined by Eqs. (9.5-1,2), and is pictured in Fig. 9.5-1.

The describing function $N(A,\phi)$ is the usual amplitude and phase relation between the sinusoid $x(t)$ and the fundamental harmonic component of $y(t)$.

This figure, in 4 parts, consists of plots of $-1/N(A,\phi)$ for $n = 2, 4, 6, 8$ and a range of values of both $A$ and $\phi$. The solid curves correspond to constant values of $A$, and various values of $\phi$ are indicated. At other locations within the envelope of these curves, $-1/N(A,\phi)$ exists for other values of $A$ and $\phi$ not shown.

The limiting values of these describing functions are

$$\lim_{A \to 0} \left( -\frac{Dk}{T_s} \frac{1}{N} \right) = \frac{1}{2} \sin \phi \left/ \phi - 270^\circ \right. \quad n = 2$$

$$= 1 \left/ -180^\circ \right. \quad n > 2$$

$$\lim_{A \to \infty} \left( -\frac{Dk}{T_s} \frac{1}{N} \right) = \frac{\pi kA}{4 T_s} \left/ \phi - 180^\circ \right. \quad \text{all } n$$

where in each case $\phi$ may take any value in the range

$$0 < \phi < \frac{360}{n}$$
Figure F-2a  $T = 2T_s$
Figure F-2b  $T = 4T_s$
Figure F-2c  $T = 6T_1$
Figure F-2d  \( T = 8T_s \)