

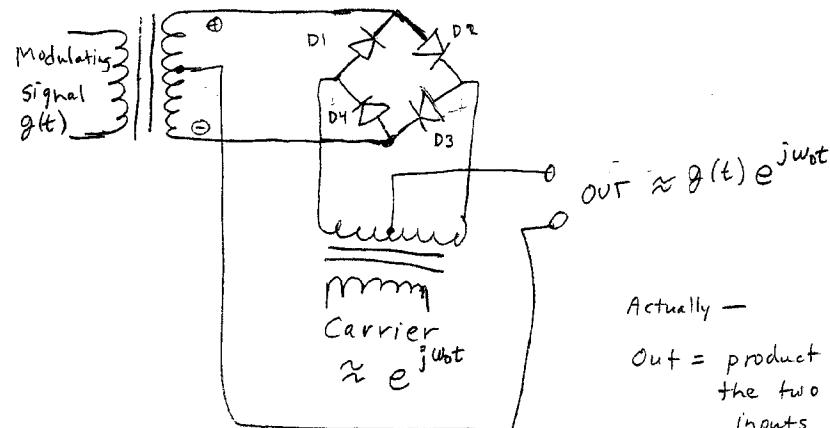
Multiplication circuits

2D-1

Make an approximation -

Use a square wave for the carrier,
then filter out the harmonics.

Here's a simple diode "ring modulator".



Actually -
Out = product of
the two
inputs

Neither input
appears at the output!

Consider --

Carrier is + ... D1, D2 conduct placing \oplus version
of $g(t)$ on output.

Carrier is - D3, D4 conduct placing \ominus version
of $g(t)$ on output.

Actually - With real diodes, the exponential characteristic
turns it into a real multiplier!

Convolution

2D-2

Recall ---

$$g_1(t) * g_2(t) = \int_{-\infty}^{\infty} g_1(\tau) g_2(t-\tau) d\tau$$

— Given a signal $g_1(t)$ and an impulse response $g_2(t)$
this gives us the response to $g(t)$.

$$g_1(t) * g_2(t) \Leftrightarrow G_1(w) G_2(w)$$

by symmetry:

$$g_1(t) g_2(t) \Leftrightarrow \frac{1}{2\pi} G_1(w) * G_2(w)$$

Proof in text

Multiplication in the frequency domain
corresponds to convolution in the time domain

This is what linear filter circuits do.
Like Laplace transforms.

This tells us --

Bandwidth of the product of two signals

= the sum of the bandwidths
of the two signals.

Time differentiation and time integration

2D-3

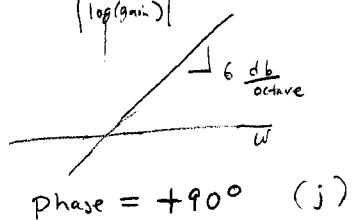
$$\text{if } g(t) \Leftrightarrow G(w)$$

then

$$\frac{dg}{dt} \Leftrightarrow jw G(w)$$

6 db/octave slope
phase = 90°

→ A differentiator is a circuit with a Frequency response like this:

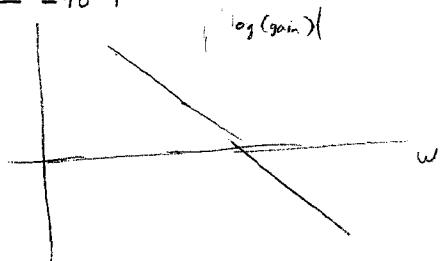


$$\int_{-\infty}^t g(\tau) d\tau = \frac{G(w)}{jw} + \pi G(0) \delta(w),$$

initial condition

-6 db/octave slope

proof in text



Signal transmission through a Linear system

2D-4

(3.4)

From S+T -- For LTI, CT system

$$y(t) = g(t) * h(t) \quad (\text{convolution})$$

using Fourier transforms --

$$Y(w) = G(w) H(w)$$

multiply
the transform
of the signal
by the transform
of the impulse
response.

$H(w)$ is the spectral response of the system, often called frequency response,

Distortionless transmission —

Output waveform is a replica of input waveform, except for a multiplicative constant, and time delay

In communications -- Frequency response and phase errors are considered to be distortion.

Consider : Audio — Amplitude errors are important
Phase errors less so.

Video — Phase errors are important
Amplitude errors less so.

Usually, we will have a spec on how much distortion is acceptable.

A distortionless system is:

$$y(t) = k g(t - t_d)$$

↑ ↗
Amplitude Scaling time delay

← are OK.

2D-5

Fourier transform:

$$Y(w) = k G(w) e^{-j w t_d}$$

↑
phase plot will be
a straight line --
linear phase.

3.5 Filters

Only a quick mention.

Be aware that filters are necessary,
but we won't design them here.

2D-6

Distortion (3.6) causes, types, etc.

Linear distortion — Due to errors in frequency response.
(Magnitude + phase)

Often caused by filters,

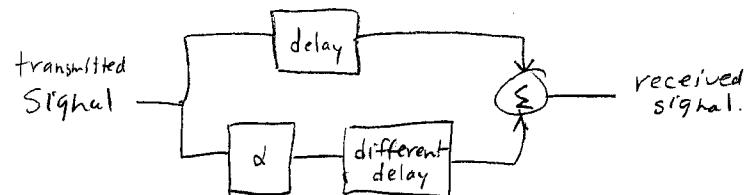
Channel nonlinearities

Nonlinear distortion in amplifiers.
" " in mixers.

→ Need clever design to eliminate distortion, but still mix.

Multipath

Often a signal will travel by more than one path.



Example: Ghosts on TV.

Fading Channels vary with time — use automatic gain control.