SerDes analog circuits description

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Introduction

The netlists presented in this article can be seen as circuits if a netlist-to-schematic conversor (such as NetlistViewer - https://sourceforge.net/p/netlistviewer/wiki/Home/) is employed.

Employed notation:

i A DC only voltage/current is represented by an italic uppercase letter(s) followed by italic uppercase subscript letter(s).

A DC voltage drop across the *GATE* and *SOURCE* of a transistor is represented by V_{GS}.

ii An AC only voltage/current is represented by an italic lowercase letter(s) followed by italic lowercase subscript letter(s).

An AC voltage drop across the *GATE* and *SOURCE* of a transistor is represented by v_{gs}.

iii A combined DC and AC voltage/current is represented by an italic uppercase letter(s) followed by italic lowercase subscript letter(s).

A combined DC and AC voltage drop across the *GATE* and *SOURCE* of a transistor is represented by V_{gs}.

An example of such notation is presented in Figure 1.

1 Analysis of an RC channel

1.1 Transfer function

Consider the circuit

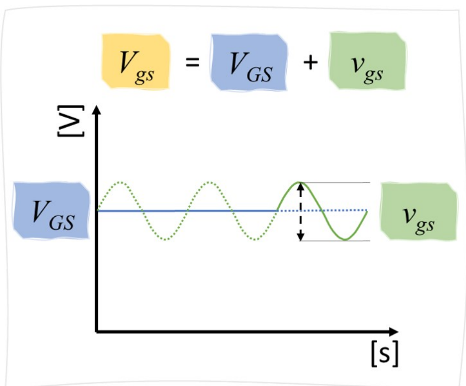

Figure 1: Examples of the employed notation in this work.

Netlist of an RC circuit

```
.SUBCKT RCchannel vin vout
R1 vin vout R
C1 vout gnd! C
.ENDS
```

At node vout(s):

$$v_{out}(s) = i(s) \cdot 1/(s \cdot C)$$

$$v_{in}(s) - v_{out}(s) = i(s) \cdot R$$

$$v_{in}(s) - i(s) \cdot 1/(s \cdot C) = i(s) \cdot R$$

$$v_{in}(s) = i(s) \cdot (R + 1/(s \cdot C))$$

Thus

$$\frac{v_{out}(s)}{v_{in}(s)} = H(s) = \frac{i(s) \cdot 1/(s \cdot C)}{i(s) \cdot (R + 1/(s \cdot C))}$$

Transfer function for an RC circuit

$$H(s) = \frac{\omega_a}{s + \omega_a}$$

Where $\tau = R \cdot C$ and $\omega_a = 1/\tau$.

1.2 Impulse response

Applying the inverse Laplace transform in the transfer function, it is obtained:

Impulse response for an RC circuit

$$h(t) = \omega_a \cdot \exp(-t * \omega_a)$$

for t > 0.

1.3 Magnitude of the transfer function

$$|H(s)| = |\frac{\omega_a}{s + \omega_a}|$$

Magnitude of H(s)

$$|H(s)| = \frac{\omega_a}{\sqrt{w^2 + \omega_a^2}}$$

1.4 Phase of the transfer function

$$\theta(w) = \arctan\left(\frac{\Im H(w)}{\Re H(w)}\right)$$

$$H(w) = \frac{\omega_a}{i \cdot \omega + \omega_a} = \frac{\omega_a \cdot (-i \cdot \omega + \omega_a)}{(i \cdot \omega + \omega_a) \cdot (-i \cdot \omega + \omega_a)}$$

$$H(w) = \frac{\omega_a^2 - i \cdot \omega \cdot \omega_a}{\omega^2 + \omega_a^2}$$

$$\Re H(w) = \frac{\omega_a^2}{\omega^2 + \omega_a^2}$$

$$\Im H(w) = \frac{-\omega \cdot \omega_a}{\omega^2 + \omega_a^2}$$

Phase of H(w)

$$\theta(w) = \arctan\left(-\omega/\omega_a\right)$$

1.5 Quantization of the model

Considering that $\omega_a = \omega_d/FS$, where FS is the sampling frequency, the quantized model is:

Transfer function for an RC circuit

$$H[m] = \frac{\omega_d/FS}{s + \omega_d/FS}$$

Where m is a discrete frequency vector.

Impulse response for an RC circuit

$$h[n] = (\omega_d/FS) \cdot \exp(-n * (\omega_d/FS))$$

Where n is a discrete time vector.

Magnitude of H(w)

$$|H[m]| = \frac{\omega_d/FS}{\sqrt{w^2 + (\omega_d/FS)^2}}$$

Phase of H(w)

$$\theta[m] = \arctan\left(-\omega/(\omega_d/FS)\right)$$

2 Analysis of a constant time linear equalizer

2.1 Transfer function

Consider the circuit

Netlist of a CTLE

```
.SUBCKT CTLE vinp vinn voutp voutn gnd!
R1 gnd! voutp RD
M1 voutp vinp vs1 0 M1
I1 vs1 gnd! I1
R2 gnd! voutn RD
M2 voutn vinn vs2 0 M2
I2 vs2 gnd! I1
R3 vs1 vs2 RS
C1 vs1 vs2 CS
.ENDS
```

Its transfer function is:

Transfer function for a CTLE circuit

$$H(s) = \frac{-g_m \cdot R_D \cdot (s+\omega_a)}{(s+\omega_a \cdot (\tau+h))}$$

Where $\tau = RS \cdot CS$, $\omega_a = 1/\tau$, and $h = g_m \cdot RS/2$.

2.2 Impulse response

Transfer function for a CTLE circuit

$$h(t) = -g_m \cdot R_D \cdot \omega_a \cdot (1 - h - \tau) \cdot exp(-t \cdot \omega_a \cdot (h + \tau))$$

For t > 0.

2.3 Magnitude of the transfer function

$$|H(w)| = \frac{g_m \cdot R_D \cdot \sqrt{w_a^2 + w^2}}{\sqrt{(w_a \cdot (\tau+h))^2 + \omega^2}}$$

2.4 Phase of the transfer function

$$\Re H(w) = \frac{g_m \cdot R_D \cdot (\omega^2 + \omega_a^2 \cdot (\tau+h))}{\omega^2 + \omega_a^2 \cdot (\tau+h)^2}$$

$$\Im H(w) = \frac{gm \cdot R_D \cdot \omega \cdot \omega_a \cdot (\tau+h-1)}{\omega^2 + \omega_a^2 \cdot (\tau+h)}$$

Phase of H(w)

$$\theta(w) = \arctan \frac{\omega \cdot \omega_a \cdot (\tau+h-1)}{\omega^2 + \omega_a^2 \cdot (\tau+h)^2}$$

2.5 Quantization of the model

Considering that $\omega_a = \omega_d/FS$, where FS is the sampling frequency, the quantized model is:

Transfer function for a CTLE circuit

$$H[m] = \frac{-g_m \cdot R_D \cdot (s + (\omega_d/FS))}{(s + (\omega_d/FS) \cdot (\tau + h))}$$

Transfer function for a CTLE circuit

$$h[n] = -g_m \cdot R_D \cdot (\omega_d/FS) \cdot (1 - h - \tau) \cdot exp(-n \cdot (\omega_d/FS) \cdot (h + \tau))$$

Magnitude of H(w)

$$|H[m]| = \frac{g_m \cdot R_D \cdot \sqrt{(\omega_d/FS)^2 + \omega^2}}{\sqrt{((\omega_d/FS) \cdot (\tau + h))^2 + \omega^2}}$$

Phase of H(w)

$$\theta[m] = \arctan \frac{\omega \cdot (\omega_d/FS) \cdot (\tau + h - 1)}{\omega^2 + (\omega_d/FS)^2 \cdot (\tau + h)^2}$$

3 Example code

An example code for such study can be found at: https://github.com/faverosantos/SerDes

References