



The TRAC Integrate Function and Low Pass Filters

Ian Shaw

The TRAC family of totally reconfigurable Field Programmable Analog Devices offers an integrated path from signal processing problems to working silicon solutions - in minutes!

Introducing a Top-Down, Structured design discipline, TRAC enables rapid implementation, prototyping and product release. Rather than designing at the component level, TRAC champions a Computational Approach. Using eight simple mathematical building-blocks, any transfer function can be implemented on TRAC, and more besides!

With a combination of programmable silicon and design software, TRAC brings a truly Integrated Route to signal processing problem solving, providing designers with benefits formerly associated only with programmable digital devices, and offering a path to Custom Silicon for higher volume users.

Introduction

The TRAC integrate (INT) function, shown in Figure 1 which is one of the options of the AUX function, is a true mathematical integrator. This note will attempt to show the differences between a true mathematical integrator, a practical mathematical integrator, a

TRAC simulation of a low pass filter and a practical TRAC low pass filter.

The TRAC Integrate Function (INT)

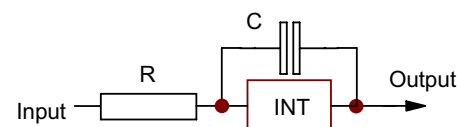


Figure 1
The TRAC Integrate Function

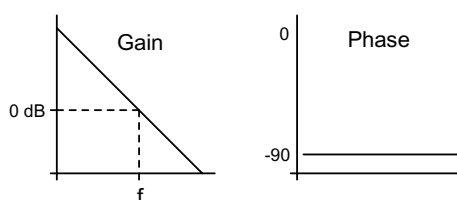


Figure 2
Gain & Phase Response of a True Integrator

The INT function is a true mathematical integrator and as such has the gain and phase characteristics shown in Figure 2.

The gain is 0dB when the impedance of the capacitor (C) is equal to the resistance (R). At this point the frequency (f) will be:

$$f = 1 / 2 \pi RC$$



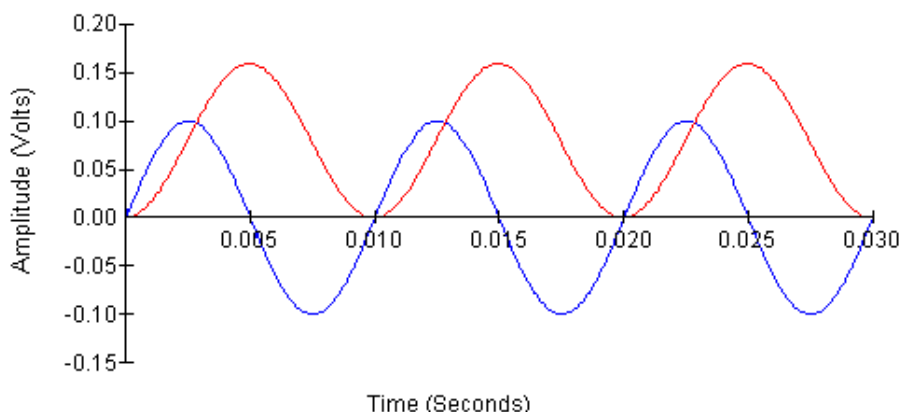


Figure 3
Input & Output Waveforms of a True Integrator

For this to occur at 10kHz, for example, the value entered in the INT cell would be 62814 (This is the reciprocal of the RC product obtained when R=7.96 k Ω and C=2nF.) These values are used in a practical integrator example shown later.

The phase shift is a constant -90° at all frequencies. The INT function truly integrates the input signal giving the area under the curve. If the input is a sine wave the output will be a cosine wave, increasing during the positive half cycle and finishing at zero after a full cycle. (See Figure 3). In actual practice all TRAC cells invert and the output in this case would actually be negative, but it still represents the area under the curve.

A theoretical integrator would have a very high gain at low frequencies, whereas a practical component is limited by the open loop gain of the amplifier.

Figure 4 shows the gain and phase

response of an integrator with R = 7.96 k Ω and C = 2 nF. The frequency at which the impedance of the capacitor equals the resistor value is 10 kHz and at this frequency it will be noted that the gain is 0 dB.

The phase shift at 10 kHz is very close to 90°, measured as 89.9°. At 1 kHz the phase shift is 88.5° and at 100 Hz, 76° This is the result of the limited open loop gain of the practical amplifier in the TRAC cell. For use as a practical integrator a sensible design maximum would be to choose the resistance and capacitance combination such that the impedance of the capacitor is not more than ten times the value of the resistance at the lowest frequency of operation. i.e.

$$RC = 1/20 \pi f$$

Then at the lowest frequency of operation the gain demanded will be 20 dB and the results will approximate closely to the theoretical version of an integrator.

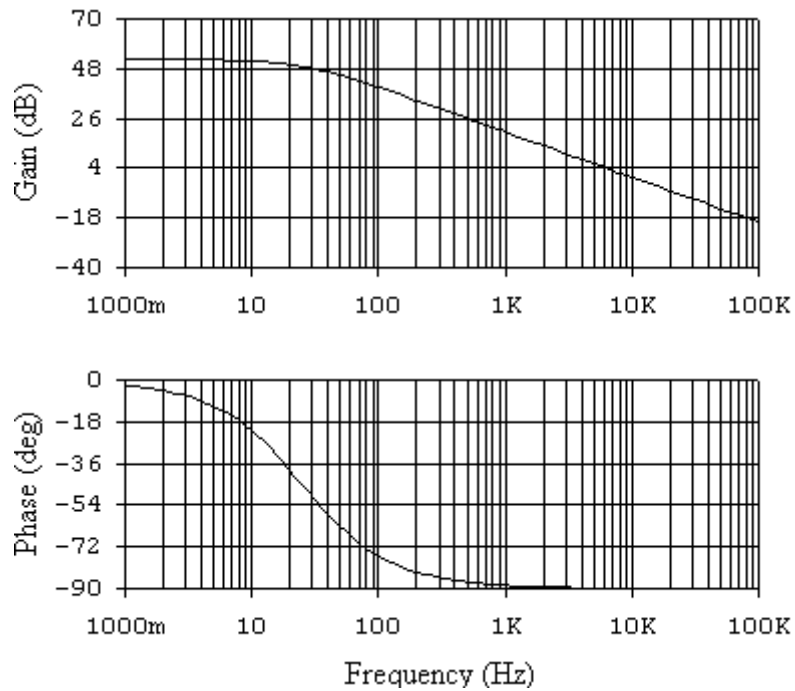


Figure 4
Gain & Phase Response of a Practical Integrator

True Low Pass Filter

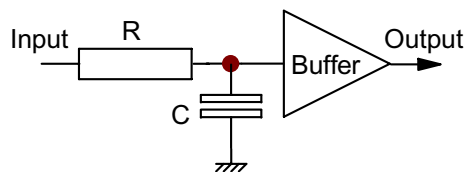


Figure 5
Low Pass Filter

The gain and phase characteristics of a first order low pass filter (Figure 5) are shown in Figure 6.

The gain for this filter will be -3dB when the impedance of the capacitor (C) is equal in value to the resistance (R). At this frequency the phase lag will be 45° and this will occur when $f = 1/2\pi RC$.

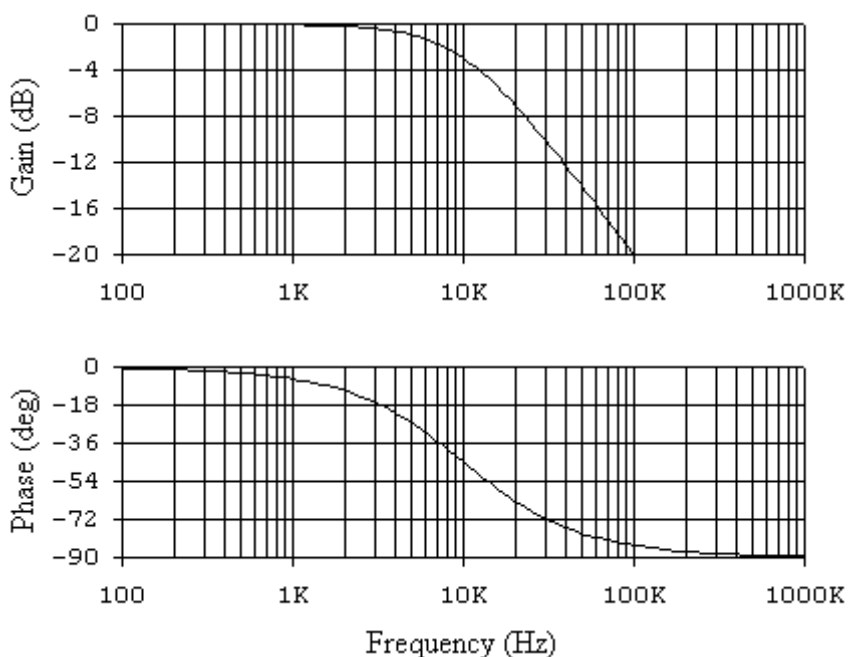


Figure 6
Gain & Phase Response of the LPF shown in Figure 5

Figure 6 shows the results for a capacitance of 2 nF and a resistance of 7.96 k Ω (corresponding to 10 kHz)

TRAC Software Emulation of a Low Pass Filter

The software emulation of the low pass filter is given in Figure 7.

If the inputs to the adder are E_a and E_b then the output will be $-(E_a + E_b)$.

The output of the integrator
(E_o) = $(E_a + E_b) / j\omega CR$.

Since $E_b = -E_o$ then $E_o = (E_a - E_o) / j\omega CR$.

Rearranging this gives us:

$$E_o/E_a = 1 / (1 + j\omega CR)$$

This defines a single pole low pass filter whose characteristics are identical with those shown in Figure 6.

TRAC Practical Low Pass Filter

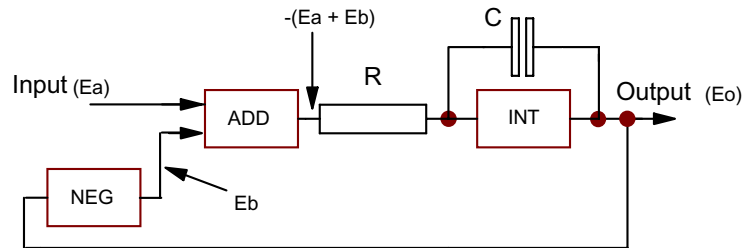


Figure 7
TRAC Software implementation of a Low Pass Filter

Whilst the above implementation of a low pass filter does work in practice it is somewhat wasteful on TRAC cells. A simpler version is shown in Figure 8.

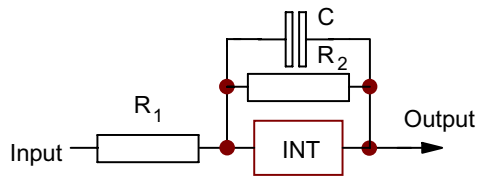


Figure 8
Practical TRAC Implementation of a Low Pass Filter

In this case the gain for this filter will be -3dB when the impedance of the capacitor is equal to the resistance (R_2). At this frequency the phase lag will be 45° and this will occur when $f = 1/2\pi R_2 C$. The low frequency gain is defined as R_2 / R_1 . For exact replication of Figure 5, R_1 and R_2 would be the same value but there is the added advantage of the ability to enter some gain or attenuation in this stage without the need for extra cells. Sensible gain values should be chosen bearing in mind the overall limitation of the cell's open loop voltage gain.

**TRAC Application Note AN24
Issue 1 September 1998**

NOTES:

TRAC

TAN24-6

NOTES:

**TRAC Application Note AN24
Issue 1 September 1998**

NOTES:

Fast Analog Solutions Ltd.
Fields New Road, Chadderton, Oldham, OL9 8NP, United Kingdom.
Tel: (+44) (0) 161 622 4567 Fax: (+44) (0) 161 622 4568
e-mail: trac@fas.co.uk Internet: <http://www.fas.co.uk>



TRAC products are supported by agents and distributors in many countries of the world. Details can be found on our web site.



A ZETEX GROUP COMPANY

This publication is issued to provide outline information only which (unless agreed by the Company in writing) may not be used, applied or reproduced for any purpose or form part of any order or contract or be regarded as a representation relating to the products or services concerned. The Company reserves the right to alter without notice the specification, design, price or conditions of supply of any product or service.

TRAC

TAN24-8