CHAPTER 2 LITERATURE SURVEY

There are literatures introducing the active-RC BIQUAD because its contracture is simple and especially less expensive. However, the passive resistors and capacitors have a large size which requires a more space in an IC and high voltage which is inappropriate for novel chip manufacturing industry.

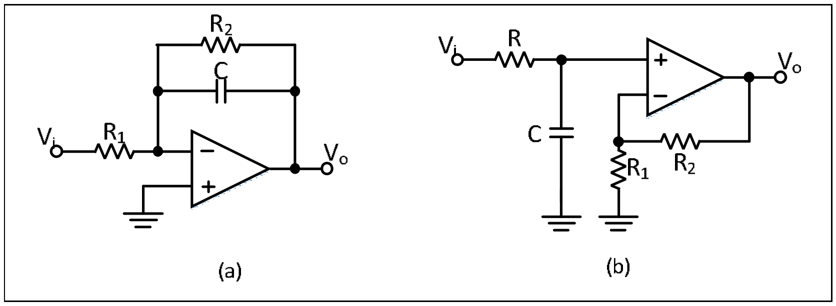

Figure 2.1 (a) A first-order lowpass circuit and (b) an alternative circuit. [1]

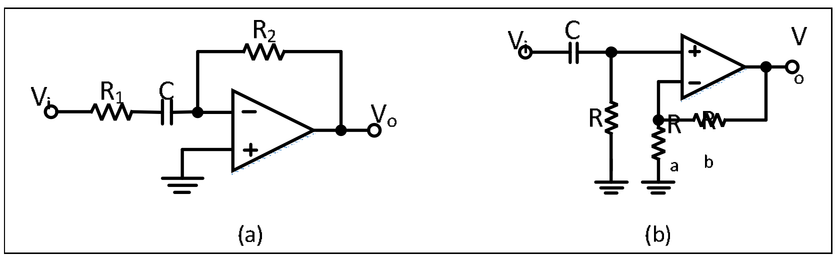

Figure 2.2 Two alternative first-order highpass circuits. [1]

In October 1982, D.T. Nguyen, M.N.Z.I.E., and L.H. Ting introduced the performance of active RC circuits at high frequency which was limited primarily by the finite gain bandwidth products (GBs) of op amps used [8]. They presented a generalized compensation technique to cover integrators and differentiators and higher-order compensation with a maximum circuit and tuning simplicity. They introduced the circuit experiment by the performance of the Tow-Thomas BIQUAD bandpass filter which was actively compensated by the proposed technique. As a result of the experiment, the BIQUAD filter could operate satisfactorily up to about 0.20 times of the effective bandwidth without a significant shift in its pole positions.

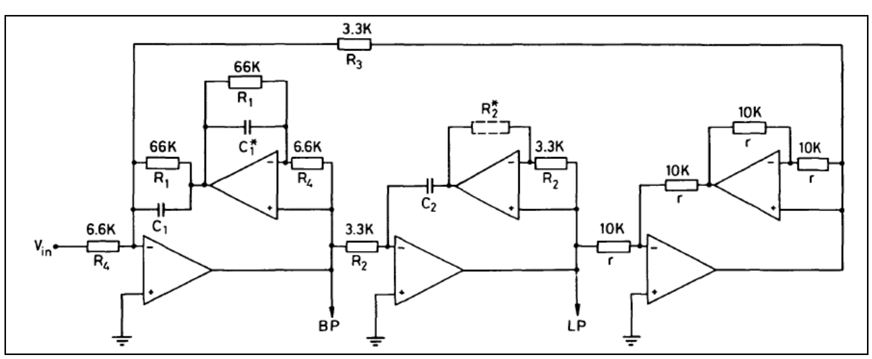

Figure 2.3 Active compensated Tow-Thomas BIQUAD filter.

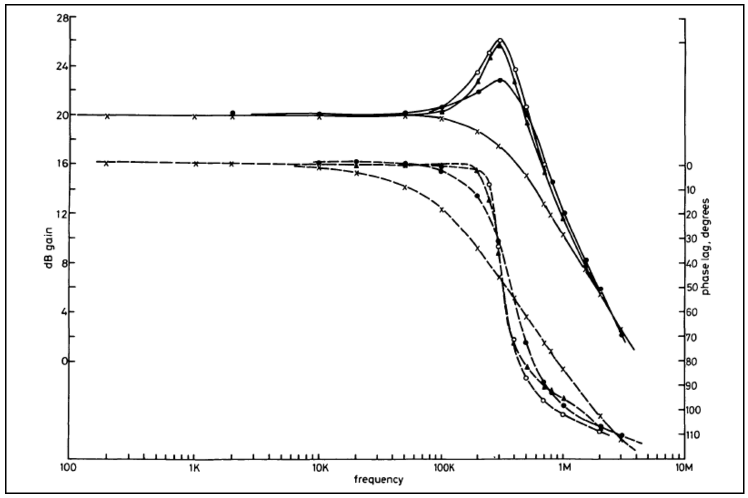

Figure 2.4 Experimental plots of amplitude and phase response of 20 dB non-inverting amplifier with various active compensation schemes.

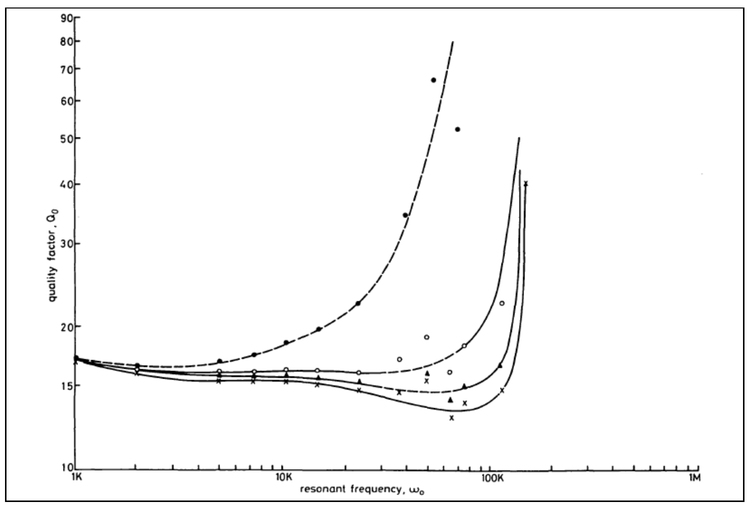

Figure 2.5 Experimental plots of variation of quality factor Q_o as a function of resonant frequency ω_o of Tow-Thomas BIQUAD

In a passive RCL-ladder network, the resister and L can be replaced by an active-R and an active-L of OTA. Therefore, the composition of OTAs and passive capacitors are called OTA-C or g_m-C applications. The OTA-C is a simple filter because it is an integrator model. It is a small size which is appropriate for producing the IC. Moreover, the OTA-C can use the general direct current, low power consumption and be able to introduce the frequency in GHz.

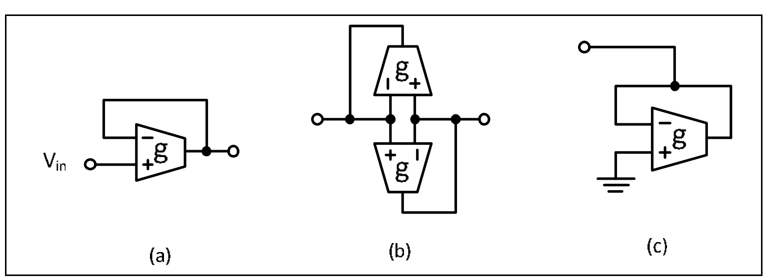

Figure 2.6 OTA simulations of resistors. [1]

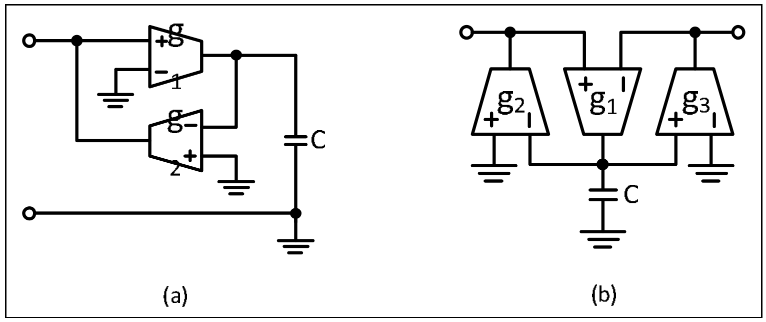

Figure 2.7 OTA simulations of inductor: (a) grounded and (b) floating. [1]

Recently, there are literatures introducing the possibility of utilizing a capacitorless bandpass BIQUAD which is actually an OTA-C BIQUAD without dominant capacitors. The transfer functions are usually managed by parasitic capacitance, which virtually renders the manual tuning impossible. Therefore, BIQUAD tuning is conducted via the genetic algorithm (GA) and the artificial neural network (ANN).

According to the GA tuned solution, the obtained parameter can satisfy the tuned response with the bandpass of 401-601 MHz and stop band attenuation at -27 dB and -34 dB. However, the tuning via the GA is quite inefficient for response evaluation which is the slowest task that is usually required. Therefore, quite long tuning time per a BIQUAD's specification is observed [6].

Table 2.1 Requirement of bandpass response (GA based ANN)

Bandpass-filter specification	
Filter type	Bandpass
Passband ripple	≤ 3 dB
Stopband attenuation	≥ 20 dB
Passband	400 MHz – 600 MHz
Stopband	≤ 50 MHz, ≥ 5 GHz (1 decade)
BIQUAD parameters	
ω_p	2.81×10^9 rad/s
f_p	447.21 MHz
Q_p	4.4615

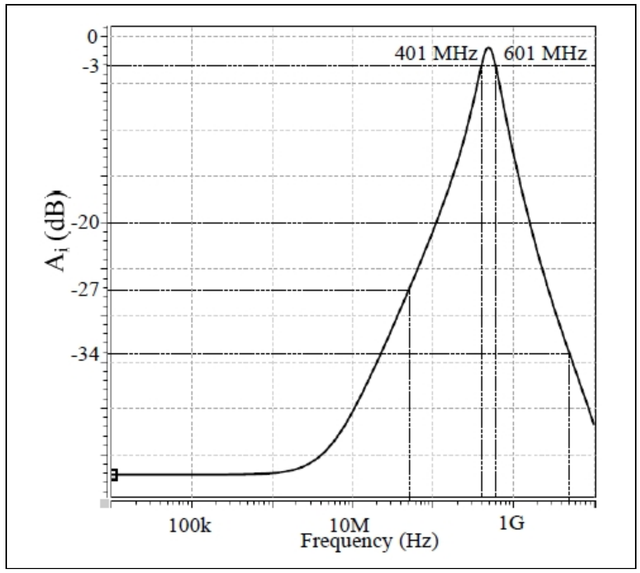

Figure 2.8 The response of obtained bandpass of GA based ANN.

Contrastingly, the ANN tuning scheme requires very little tuning time because the circuit's parameters are simply extracted as an output of the trained ANN. However, to train the ANN for fitting all predefined bias points is quite impossible especially in training with validation and test. Therefore, training without validation is utilized, which requires extremely long and impractical training time. In addition, this training method degrades the generalization of the ANN. Therefore, the trained ANN hardly provides solutions that precisely match the BIQUAD specifications [6].

Table 2.2 Specifications of bandpass response (Generally trained ANN)

Requirement	**Desired Spec.**	**Obtained Spec.**
Filter type	Bandpass	Bandpass
Passband ripple	≤ 3 dB	≤ 3 dB
Stopband attenuation	≥ 20 dB	≥ 20 dB
Passband	300 MHz – 550 MHz	300 MHz – 549 MHz
Stopband	≤ 50 MHz, ≥ 3 GHz	≤ 73 MHz, ≥ 1.68 GHz
BIQUAD parameters	**Desired Spec.**	**Obtained Spec.**
K	1	0.9963
ω_p	2.55×10^9 rad/s	2.56×10^9 rad/s
f_p	406.2 MHz	407.4 MHz
Q_p	1.621	1.6205

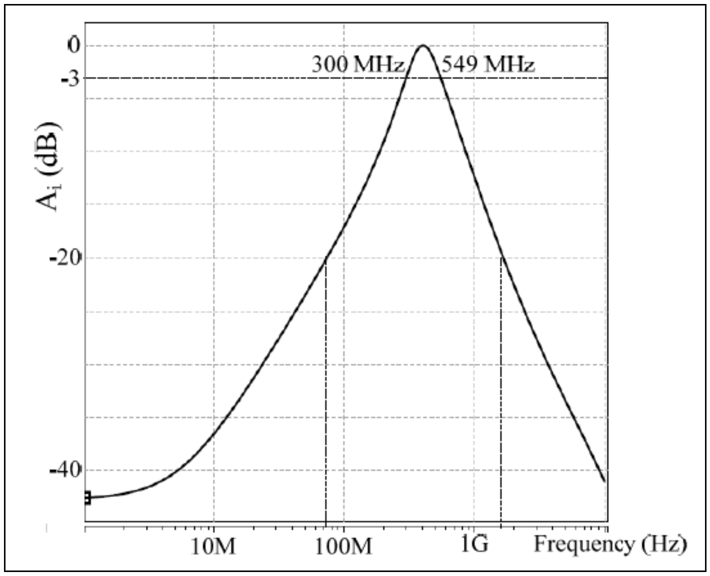

Figure 2.9 The response of obtained bandpass of ANN-generated parameter

In October 2009, Pongsuwan R, Chaisricharoen, R. and Chipipop, B. published the particle swarm optimization (PSO) which was deployed to tune a capacitorless all-OTA bandpass BIQUAD [10]. According to the experiment, PSO tuning with the large size of initial swarm was more desirable than the small one. It found the optimal part of swarm to optimize the BIQUAD specifications. Along with the tuned experiments and the same BIQUAD specifications, the results are shown in the table below.

Table 2.3 Specifications of bandpass response (PSO)

Requirement	**Desired Spec.**	**Obtained Spec.**
Passband ripple	≤ 3 dB	≤ 3 dB
Stopband attenuation	≥ 20 dB	≥ 20 dB
Passband	300 MHz – 550 MHz	299 MHz – 550 MHz
Stopband	≤ 50 MHz, ≥ 3 GHz	≤ 77 MHz, ≥ 1.68 GHz
BIQUAD parameters	**Desired Spec.**	**Obtained Spec.**
K	1	0.996
ω_p	2.55×10^9 rad/s	2.56×10^9 rad/s
f_p	406.2 MHz	407.38 MHz
Q_p	1.621	1.6187

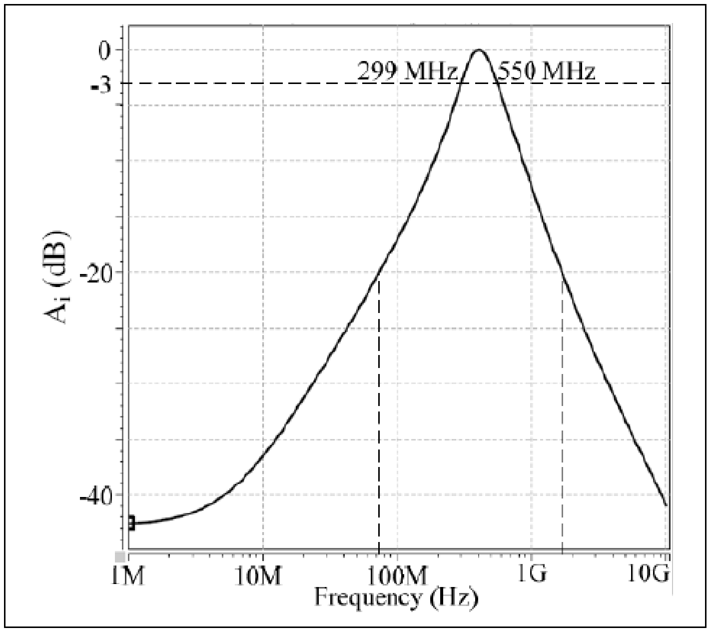

Figure 2.10 The response of obtained bandpass of PSO-based tuning.