

CHAPTER 3 RELATED THEORETICAL

3.1 The Basic of OTA

The operation transconductance amplifier (OTA) is the filter that has been implemented widely in CMOS and bipolar technology. The value of transconductance are hundreds of μS in CMOS and up to mS in bipolar. A simple active-loaded differential-pair can be configured as a single-stage OTA [11] of both plus and minus outputs as displayed in Fig. 3.1.

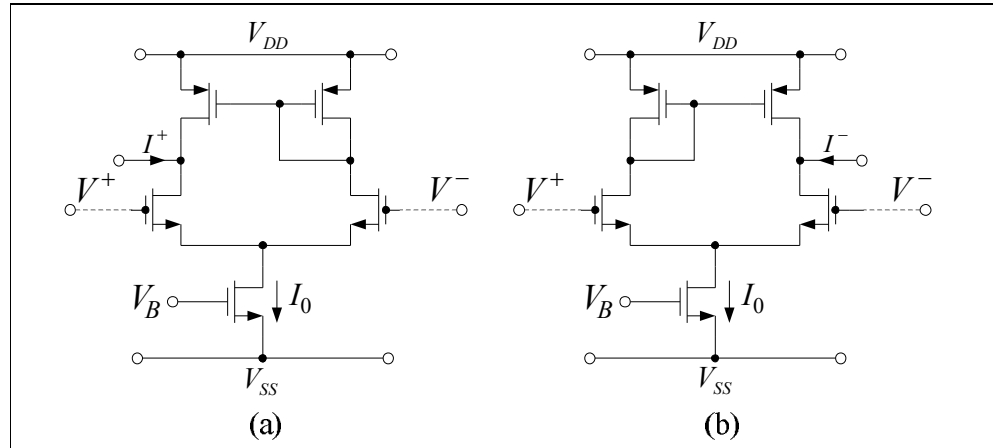


Figure 3.1 Single-stage OTA with plus (a) and minus (b) outputs [11]

The balanced-output OTA, required in BIQUAD, is simply implemented by piling up both structures in Fig. 3.1 and sharing the same input. To generate bias voltage from an external current source, only one additional NMOS transistor is required. Therefore, if n outputs are needed, the number of the required transistors (NT) is: [11]

$$\text{NT} = 5n + 1 \quad (3.1)$$

3.2 Artificial Neural Network (ANN)

ANN is a mathematical model or computational model based on biological neural networks. It consists of an interconnected group of artificial neurons and processes information using a connectionist approach to computation. Moreover, the ANN can be used to model complex relationships between inputs and outputs or to find patterns in data.

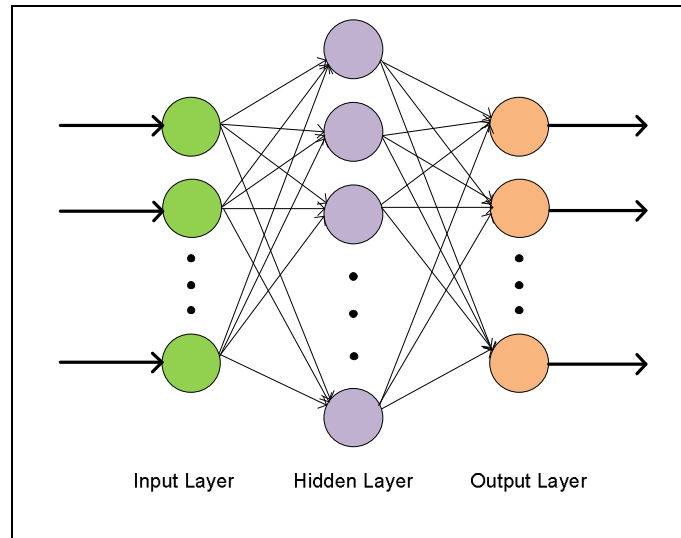


Figure 3.2 Construction of Neural Network

3.2.1 Feed-forward Backpropagation

Backpropagation is a supervised learning method which requires the desired output for the given input. Its model is simple for feed-forward networks and requires that the transfer function used by the "nodes" be differentiable. The feed-forward network is the type of an ANN architecture training model which includes the set of nodes. The network information moves in one direction, forward, from the input nodes, through the hidden nodes and to the output nodes. The input layer does not really do any process and simply copies raw information preparation into the neural network. Each node-to-node arrow represents a numeric constant called a weight. The weight is once an important parameter in the network because it is the branch relationship between the input and the hidden layer and to the accurate output pattern. The hidden layer is the capability layer to calculate and evaluate the input data, after that, it is forwarded to the output layer. Moreover, each hidden-layer node is computed independently. The output layer nodes are computed in the same way as the hidden layer nodes except that the values computed into the hidden layer nodes are now used as inputs. In addition, the number of outputs depends on network designation.

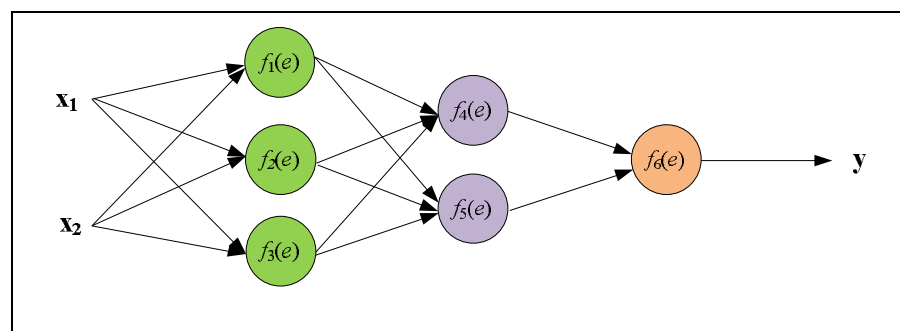


Figure 3.3 Model of backpropagation

Where the signal e is an adder output signal, and $y = f(e)$ is an output signal. The signal y is also an output signal of a neuron.

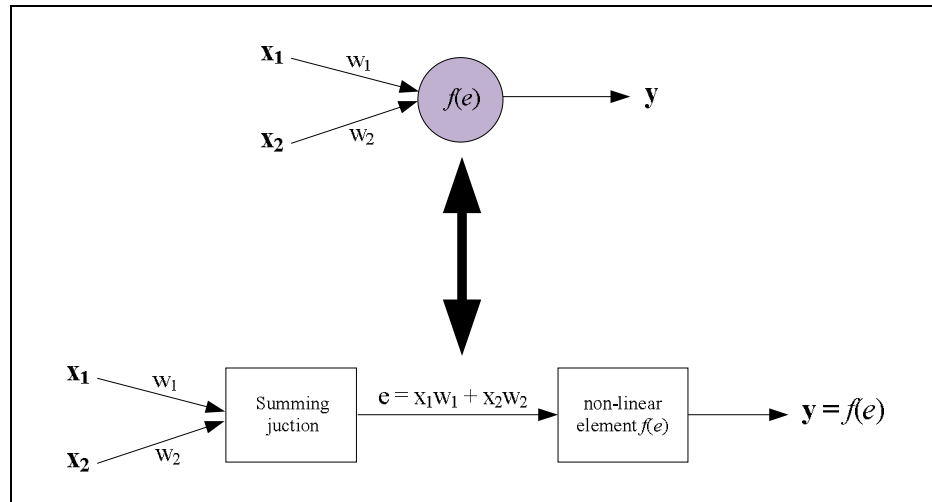


Figure 3.4 Equation of output

The data sets are required to teach the neural network. The training data set consists of input signals (x_1 and x_2) assigned with a corresponding desired output. The network training is an iterative process. In each iteration weights coefficients of nodes are modified using new data from training data set. Each teaching step starts with forcing both input signals from training set. After this stage we can determine output signals values for each neuron in each network layer. Figure 3.4 illustrates how the neuron trains the data set to get the output signal.

Where symbols x represent input data, w represent weights of connections between network input x and neuron n in input layer. At the end of equation, $y=f(e)$ represents an output function of a neuron model.

3.2.2 Neuron Model (logsig, tansig, purelin)

This is the architecture of the network that is most commonly used with the backpropagation algorithm, the multilayer feedforward network.

An elementary neuron with R inputs is shown below. Each input is weighted with an appropriate w . The sum of the weighted inputs and the bias forms the input to the transfer function f . Neurons can use any differentiable transfer function f to generate their outputs.

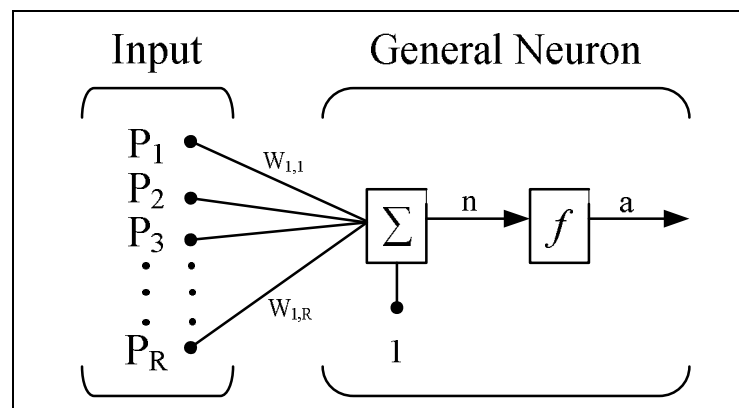


Figure 3.5 Architecture of the backpropagation network.

Where, $a = f(w_p + b)$
 R = number of elements in an input vector

3.3 BIQUAD Filter

A BIQUAD filter is a type of an active filter consisting of a two-integrator feedback loop with an inverter. In its basic configuration, it can be used as either a low-pass or band-pass filter, depending on where the output signal is taken from. We use the BIQUAD filter because it is easy to use and has enough equation to solve the problem as follows.

Table 3.1 Second-order Filter Function

Filter function	Transfer function
Low-pass	$k \frac{1}{s^2 + as + b}$
High-pass	$k \frac{s^2}{s^2 + as + b}$
Band-pass	$k \frac{s}{s^2 + as + b}$
Band-reject	$k \frac{s^2 + d}{s^2 + as + b}$
Delay equalizer	$k \frac{s^2 - as + d}{s^2 + as + b}$

The response characteristics of each filter type can be considered as shown in Figures 3.6-3.9.

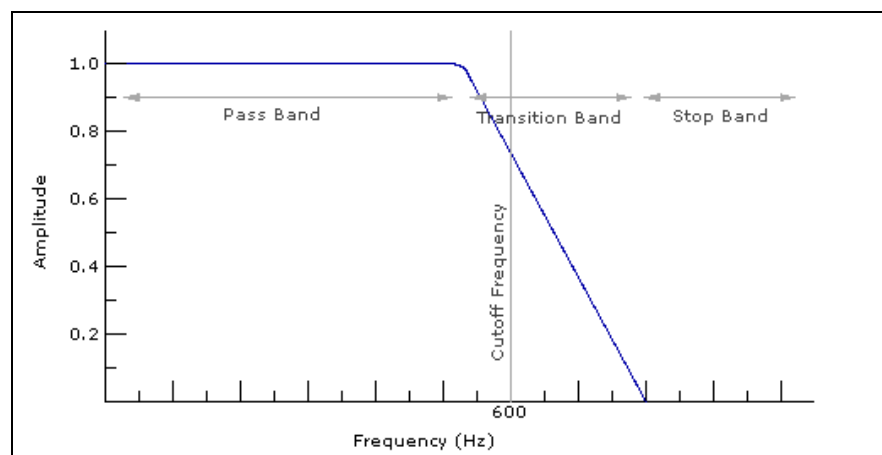


Figure 3.6 Low pass filter

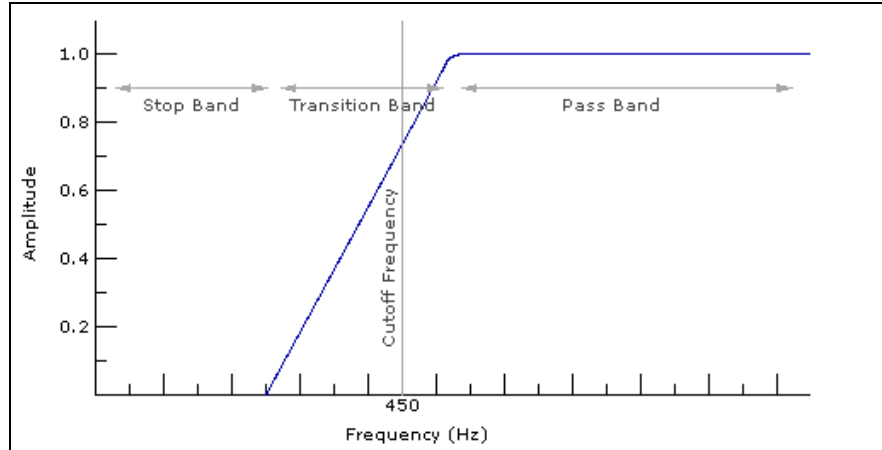


Figure 3.7 High pass filter

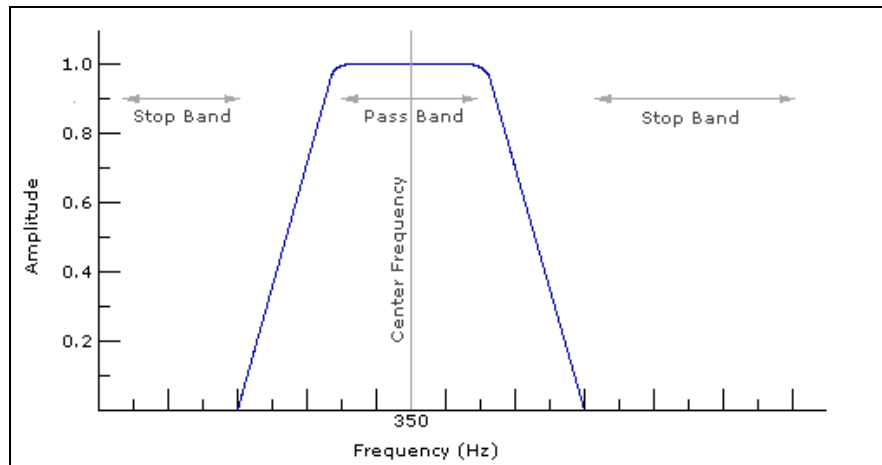


Figure 3.8 Band pass filter

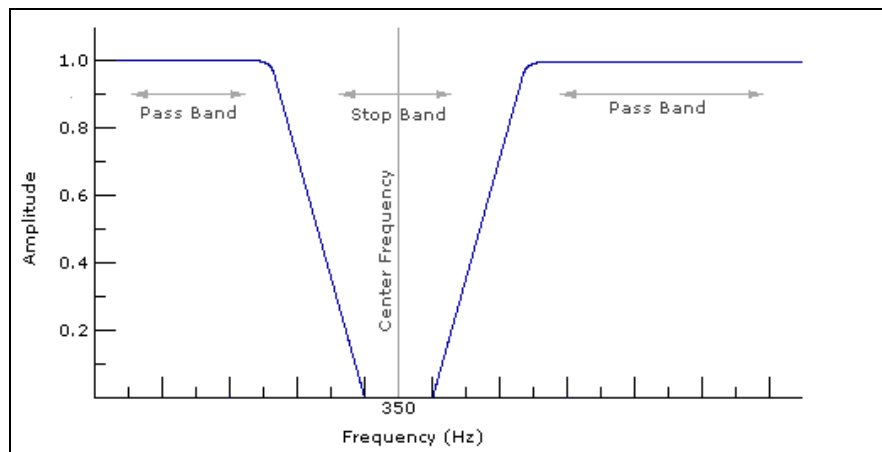


Figure 3.9 Band reject filter

This biquadratic equation can also be expressed in terms of the parameters K , ω_p , Q_z and Q_p as follows.

$$T(s) = K \frac{s^2 + \frac{\omega_z}{Q_z} s + \omega_z^2}{s^2 + \frac{\omega_p}{Q_p} s + \omega_p^2} \quad (3.2)$$

As C_2 is greater than C_1 , Q_p can be expected over unity. Therefore, low Q_p requirements are not suitable for this capacitorless BIQUAD. Assuming small deviations in C_1 , C_2 and ω_p can be tuned by adjusting the bias currents of the first and second OTAs.