

Piezoelectric Discriminators

Introduction

Ceramic discriminators are designed to be used in quadrature detection circuits to remove a FM carrier wave. These circuits receive a FM signal, like in a FM radio, and send out an audio voltage, the music that comes out of the speakers. Ceramic discriminators replaced tuned LC tank circuits with a single, non-tunable, solid state device. In order to explain how a discriminator works, it is necessary to briefly explain frequency modulation.

Principles of Frequency Modulation

Frequency modulation (FM) is a method of placing a signal onto a high frequency carrier wave for transmission. The signal is usually an audio signal, such as voice or music, at a low frequency referred to as the audio frequency (AF). This is also referred to as the modulating signal since it is used to modulate the carrier wave. The carrier wave is a high frequency signal that is used to carry the audio signal to a remote receiver. This is referred to as the radio frequency (RF) signal. For FM, the frequency of the RF signal is varied instantaneously around the center frequency in proportion to the AF signal. As the voltage level of the AF signal increases, the frequency of the RF signal is increased. As the AF voltage decreases, the frequency of the RF signal is decreased. Figure 63 illustrates this.

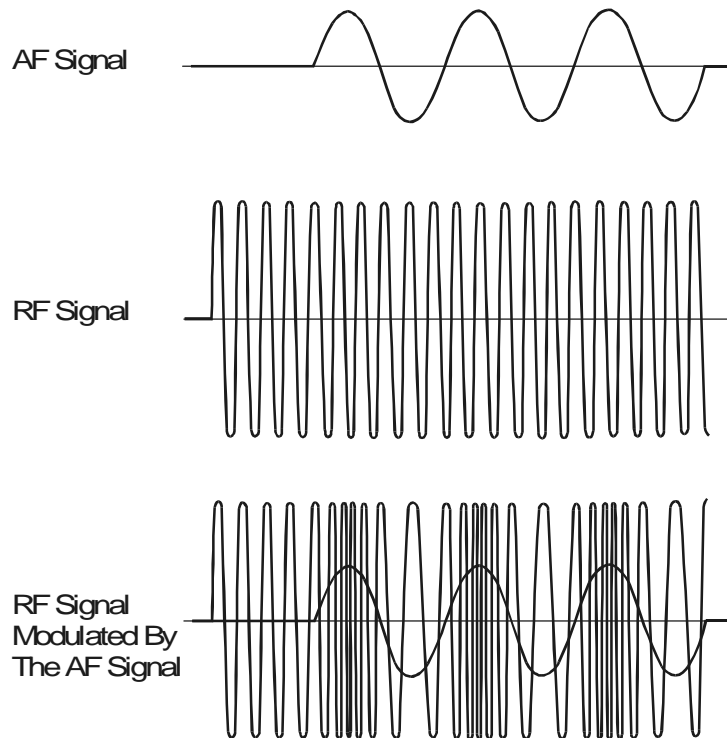


Figure 63: Generating An FM Signal

The difference between the highest frequency (when the AF is at a maximum) and the lowest frequency (when the AF is at a minimum) is called the frequency deviation. It is the function of the discriminator to recover the audio signal from this modulated RF signal by a method called quadrature detection.

Principles of Quadrature Detection

Quadrature detection is one method of stripping away a FM carrier signal and leaving the original transmitted signal.

The block diagram of a quadrature detector circuit is shown in Figure 64.

First, the IF signal is passed through a limiting amplifier where any AM signal is removed. From here, the signal is split into two parts. The first part is sent to a phase shifter. This phase shifter is a capacitor, which adds a -90°

(Figure 66)

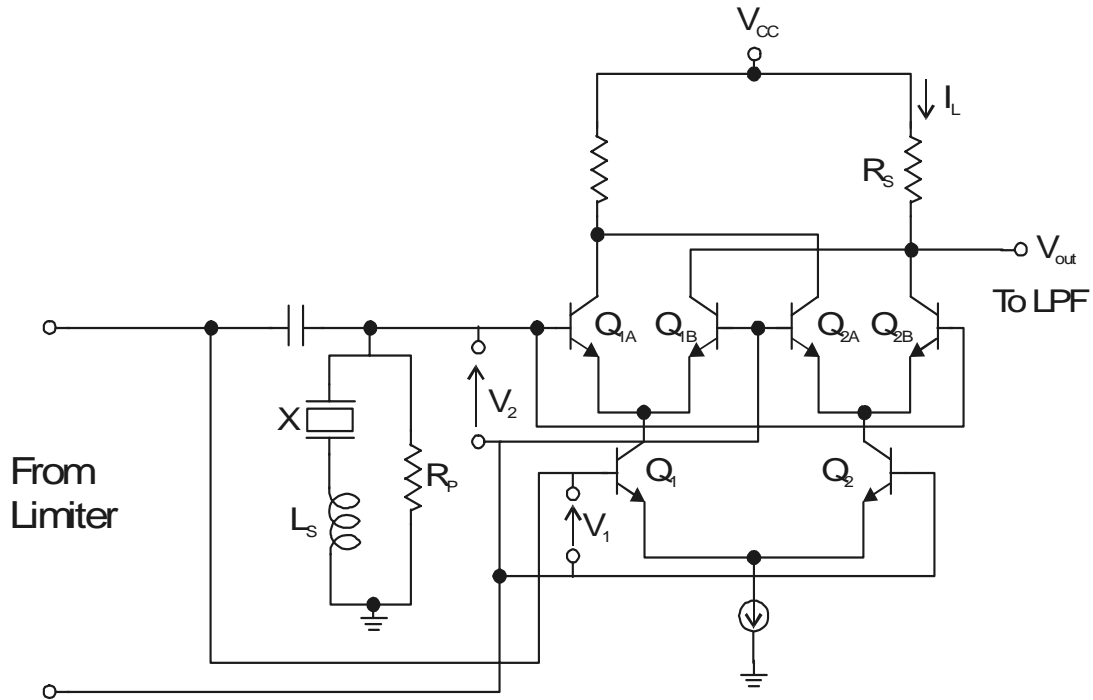


Figure 66: Balanced Demodulator Circuit

In Looking at the mixer portion of the demodulator circuit, it can be seen that current I_L will flow only when V_1 and V_2 are opposite voltages. This will cause a voltage drop across resistor R_s so will give a lower output voltage. Figure 67 shows how the output differs with the input. A square wave is shown to simplify the drawing, but the same principle applies for a sine wave. A low pass filter will average the output pulses into a DC voltage, also shown in the figure below.

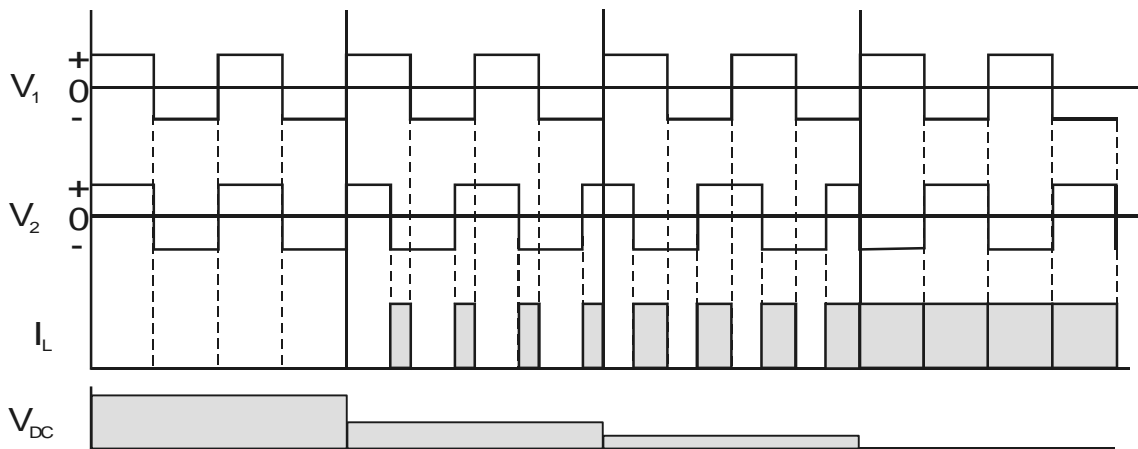


Figure 67: Signals in the Mixer Circuit

The discriminator will add more phase to the lower frequencies and less phase to the higher frequencies. This means that the demodulator will output a large voltage for input signals with a high frequency and a small voltage for signals

with a low frequency, thereby recovering the original audio signal (Figure 68)

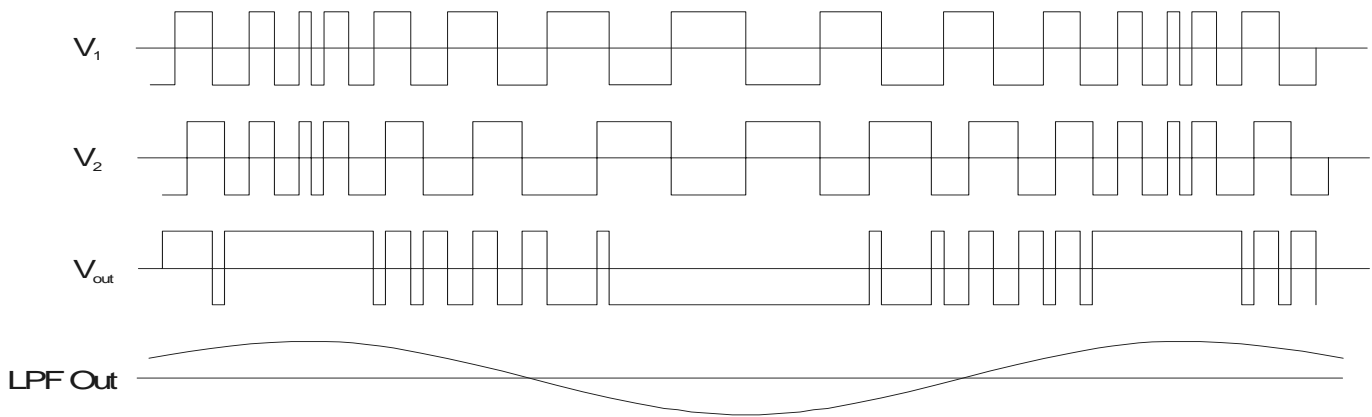


Figure 68: Input And Output Signals

The discriminator circuit was originally a LC tank circuit (Figure 69a). This circuit had to be hand tuned to the correct IF frequency. Ceramic discriminators replaced the tank circuit with a solid state device that does not require tuning (Figure 69b). The next section will discuss the operation of the discriminator.

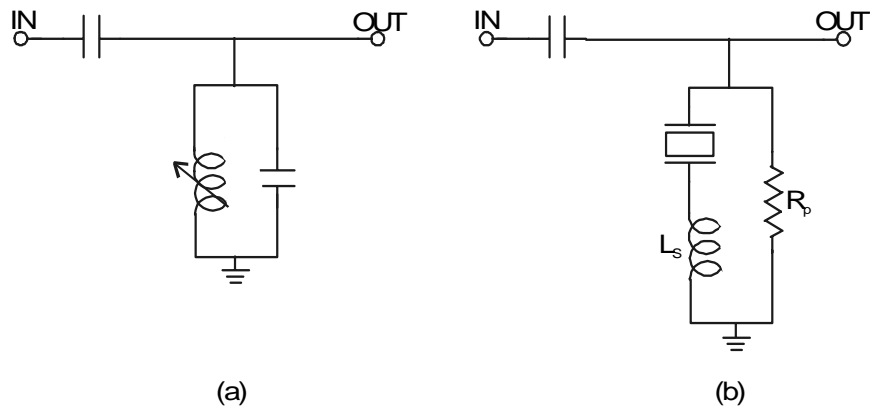


Figure 69: Discriminator Circuit

Principles of Bridge-Balance Detection

Another method of detection is to use a balanced bridge circuit. This circuit consists of 3 resistors and the discriminator connected in a bridge configuration. The output goes into a subtractor and then to the balanced demodulator circuit

shown earlier (Figure 70).

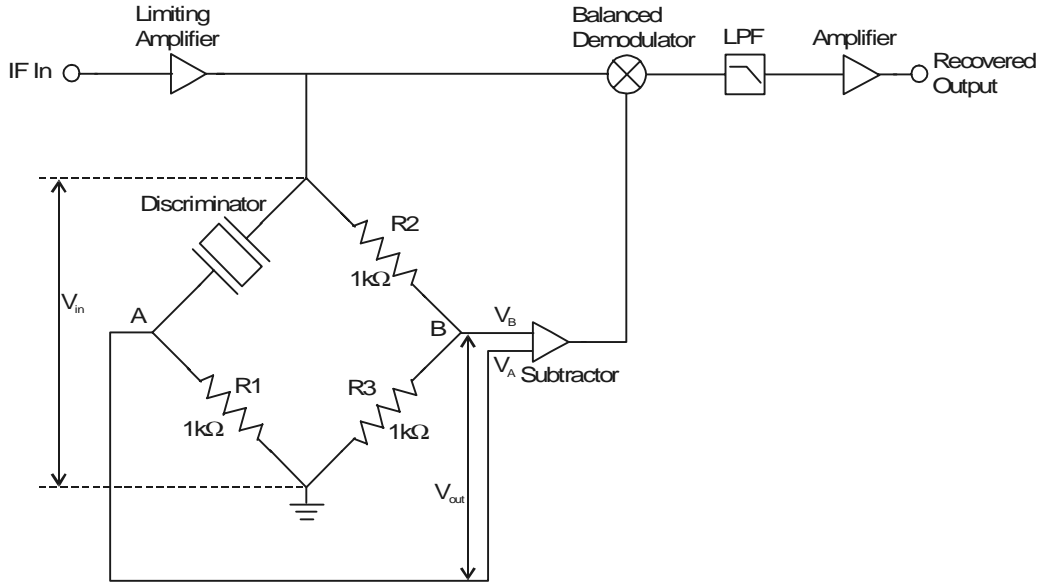


Figure 70: Balanced Bridge Circuit

This circuit utilizes both the impedance and phase responses of the discriminator. The discriminator is designed to be about $1k\Omega$ at the center frequency, so the other resistors are all $1k\Omega$. This means that as the frequency changes, the impedance and phase of the discriminator will change. This change will result in a phase shift being added to the original signal. The subtractor will take the voltage difference between points A and B and reference it to ground so that it can be fed into the balanced demodulator. Although the operation is different, the output signal of the subtractor is the same as the output signal of the quadrature detection circuit.

How Does It Work

Piezoelectric ceramic discriminators are similar to ceramic resonators. They have the impedance and phase response shown in Figure 71.

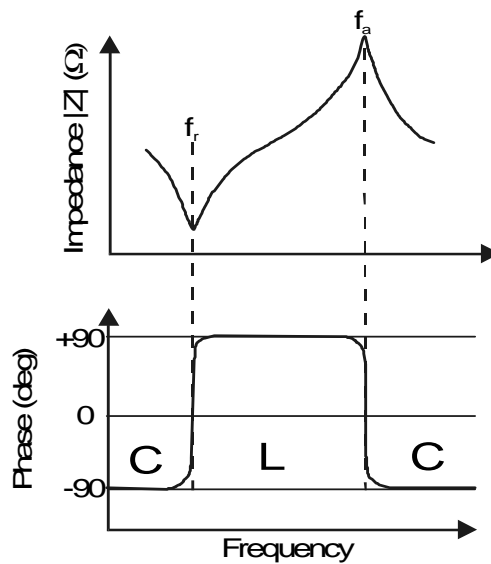


Figure 71: Resonator Impedance and Phase Plot

As can be seen from Figure 71, the impedance is a minimum at the resonant frequency, f_r , and a maximum at the anti-resonant frequency, f_a . Between these two frequencies the discriminator becomes inductive and is capacitive over all other frequencies. As stated earlier for the quadrature detection circuit, it is desired to add more phase to the lower frequencies and less phase to the higher frequencies. By adding a resistor in parallel with the discriminator, the anti-resonant impedance is lowered and the phase response is dampened. Figure 72 shows a computer simulation of the phase response of the resonator using different values for a parallel resistor.

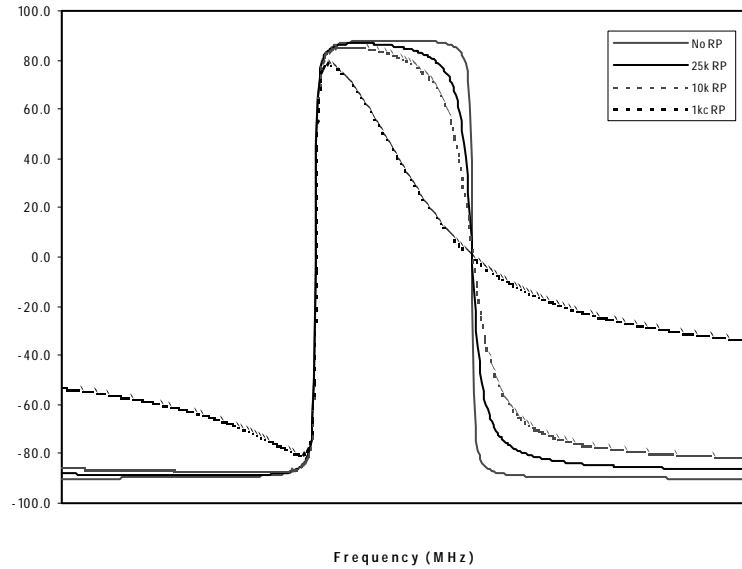


Figure 72: Computer Simulation of Resonator With Parallel Resistor

A series inductor increases the bandwidth, but this shifts the anti-resonant frequency to a higher frequency. Figure 73 shows a computer simulation of the phase response using different values for the series inductor. It also improves the symmetry of the output response. Since the inductor can also shift the center frequency of the discriminator, the design of the discriminator must compensate for this. The inductor is used for applications requiring a wide bandwidth and is generally not necessary for all applications. This manual shows the inductor in all of the circuits as a reference,

but the specific application and an IC characterization (Appendix 3) determine if it is really necessary.

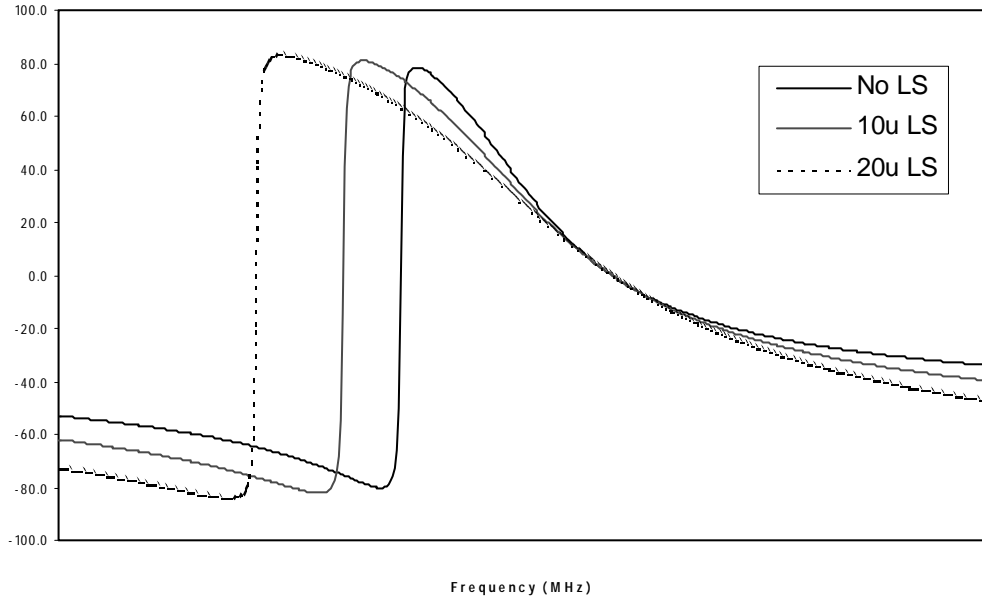


Figure 73: Computer Simulation of Resonator With Parallel Resistor and Series Inductor

From Figure 73, it can be seen that the lower frequencies would have the largest phase shift added and, as a result, would have the lowest output voltage. When a comparison is made between output voltage and frequency the result is

that the circuit has an S curve characteristic (Figure 74).

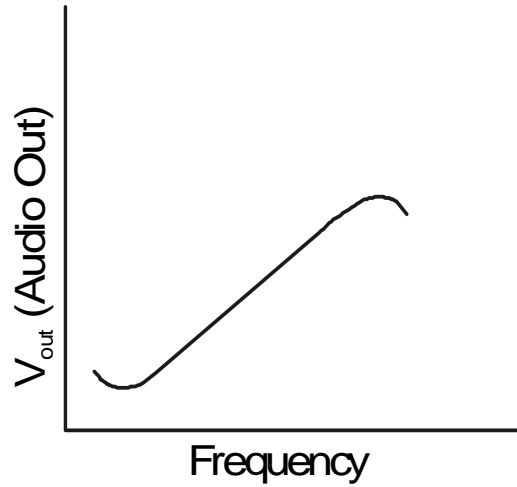


Figure 74: Discriminator S Curve Characteristic

When the discriminator is well tuned, the center of the S curve is at the IF frequency. This results in the best overall recovered audio or output voltage and also provides a margin against variations in the center frequency from part to part (Figure 75).

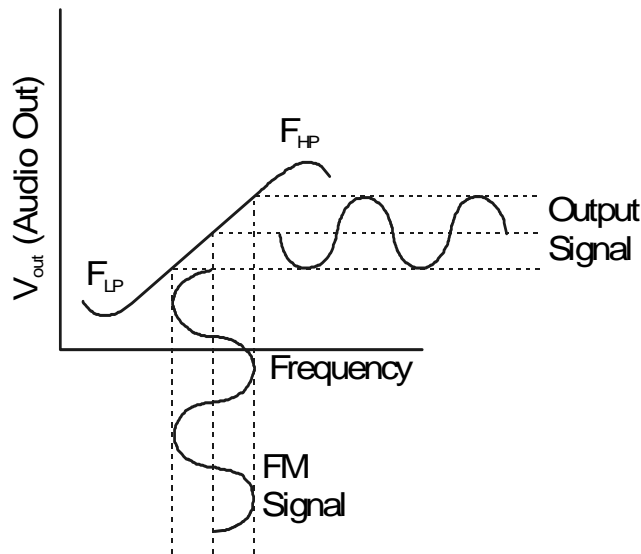


Figure 75: Well Tuned Discriminator

If the discriminator is poorly tuned and the center of the S curve is not near the center frequency, then the recovered

audio and the bandwidth would be decreased (Figure 76).

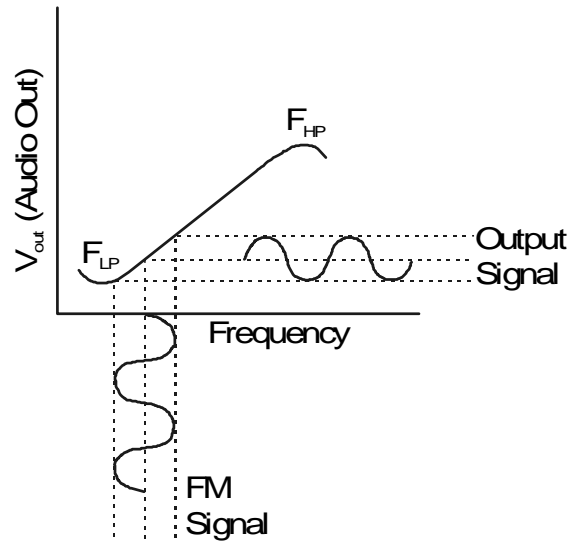


Figure 76: Poorly Tuned Discriminator

If the signal were at the minimum, F_{LP} or maximum, F_{HP} of the S curve, then the recovered audio would be a minimum and the signal would be distorted. As can be seen in Figure 77, the lower half of the wave is flipped up and a series of humps results. This leads to a completely unrecognizable output signal.

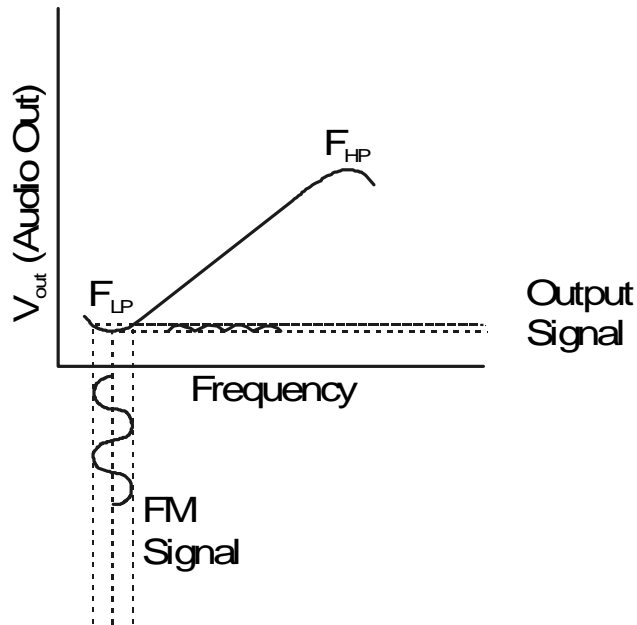


Figure 77: Distorted Output Signal

Peak separation is the distance between F_{LP} and F_{HP} . A wider peak separation gives more linear characteristics at the

center of the S curve and a wider bandwidth, but it also gives a lower recovered audio voltage (Figure 78).

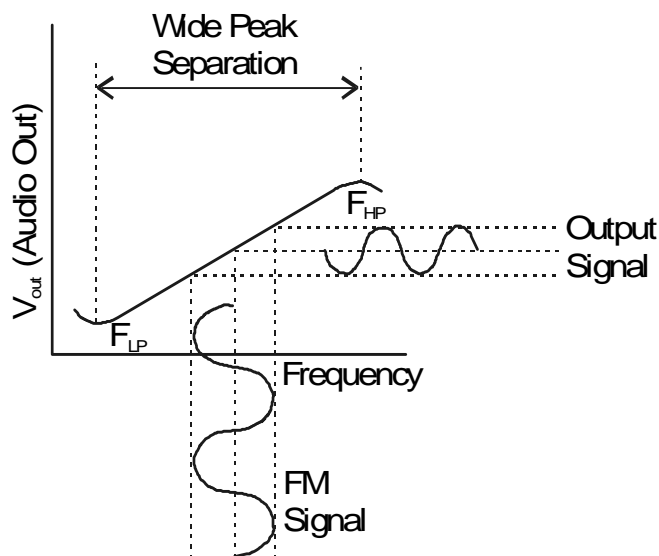


Figure 78: Wide Peak Separation

A smaller peak separation has a smaller bandwidth but gives a larger recovered audio voltage (Figure 79).

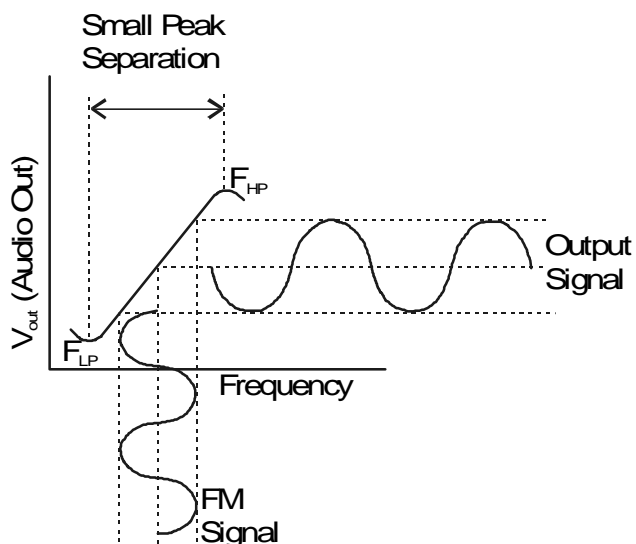


Figure 79: Narrow Peak Separation

Figure 80 shows an example of recovered audio data. Frequencies near the center frequency result in the largest output voltage. The 3dB frequencies are the two points where a line 3dB down from the maximum recovered output intersects the curve. The 3dB bandwidth is the range of frequencies between these two points, and should be close to the

frequency deviation. The two minimum points on the recovered audio curve correspond to F_{HP} and F_{LP} of the S curve.

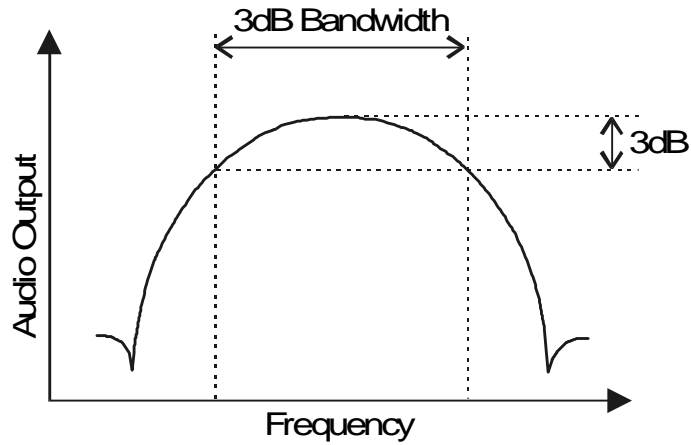


Figure 80: Recovered Audio Curve

Some distortion is introduced by the discriminator because it is not a truly linear device., as shown by the “S” curve in Figure 81.

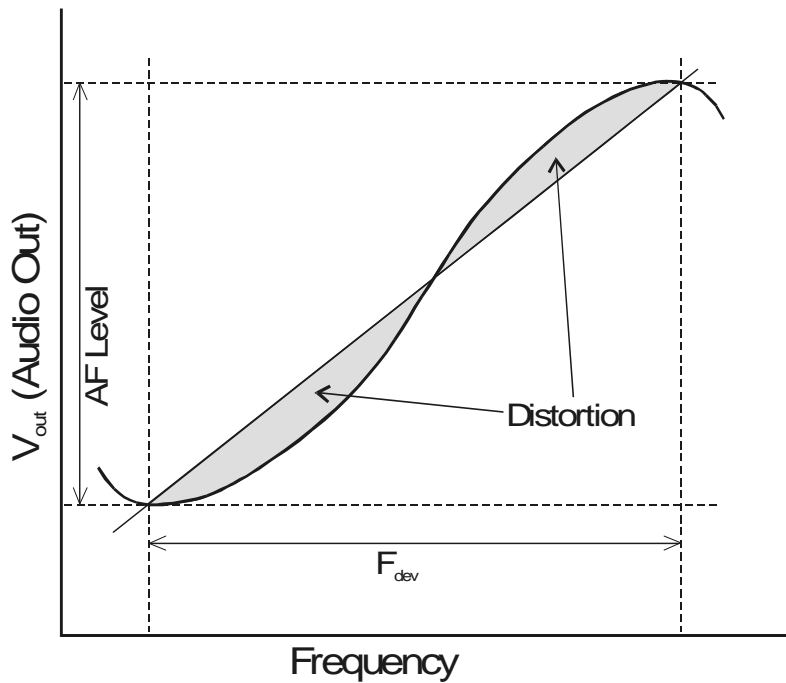


Figure 81: Discriminator Distortion

This distortion is smallest at the center frequency of the discriminator where the discriminator is at its most linear point. This distortion can be compensated for in the design of the circuit and minimized by a good discriminator. Figure 82 shows an example of a graph of recovered audio and total harmonic distortion for the quadrature detection circuit. The bridge detection circuit has a more linear phase characteristic, resulting in a wider bandwidth and flat distortion (Figure

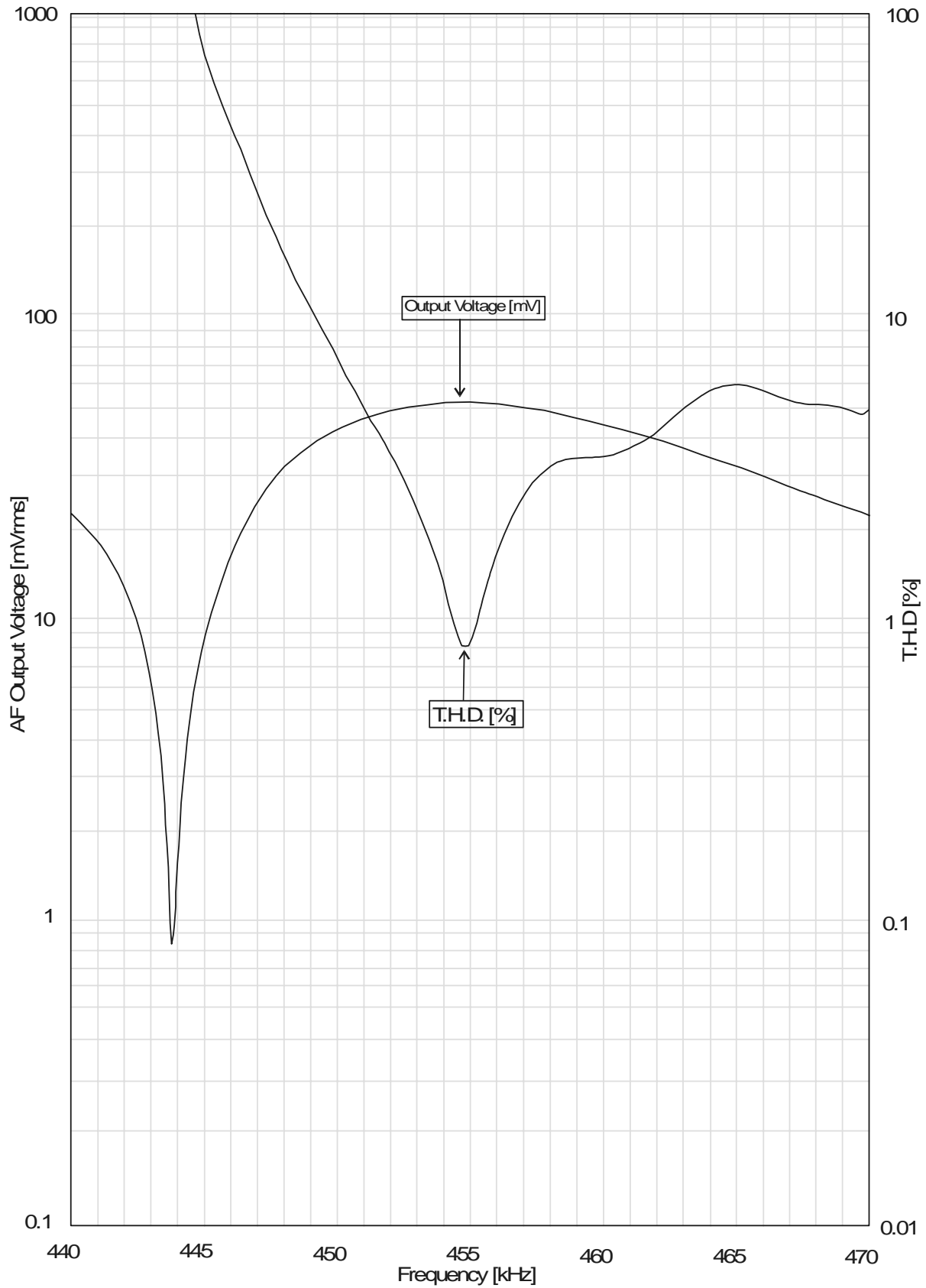


Figure 82: Example of Recovered Audio and Total Harmonic Distortion for Quadrature Detection

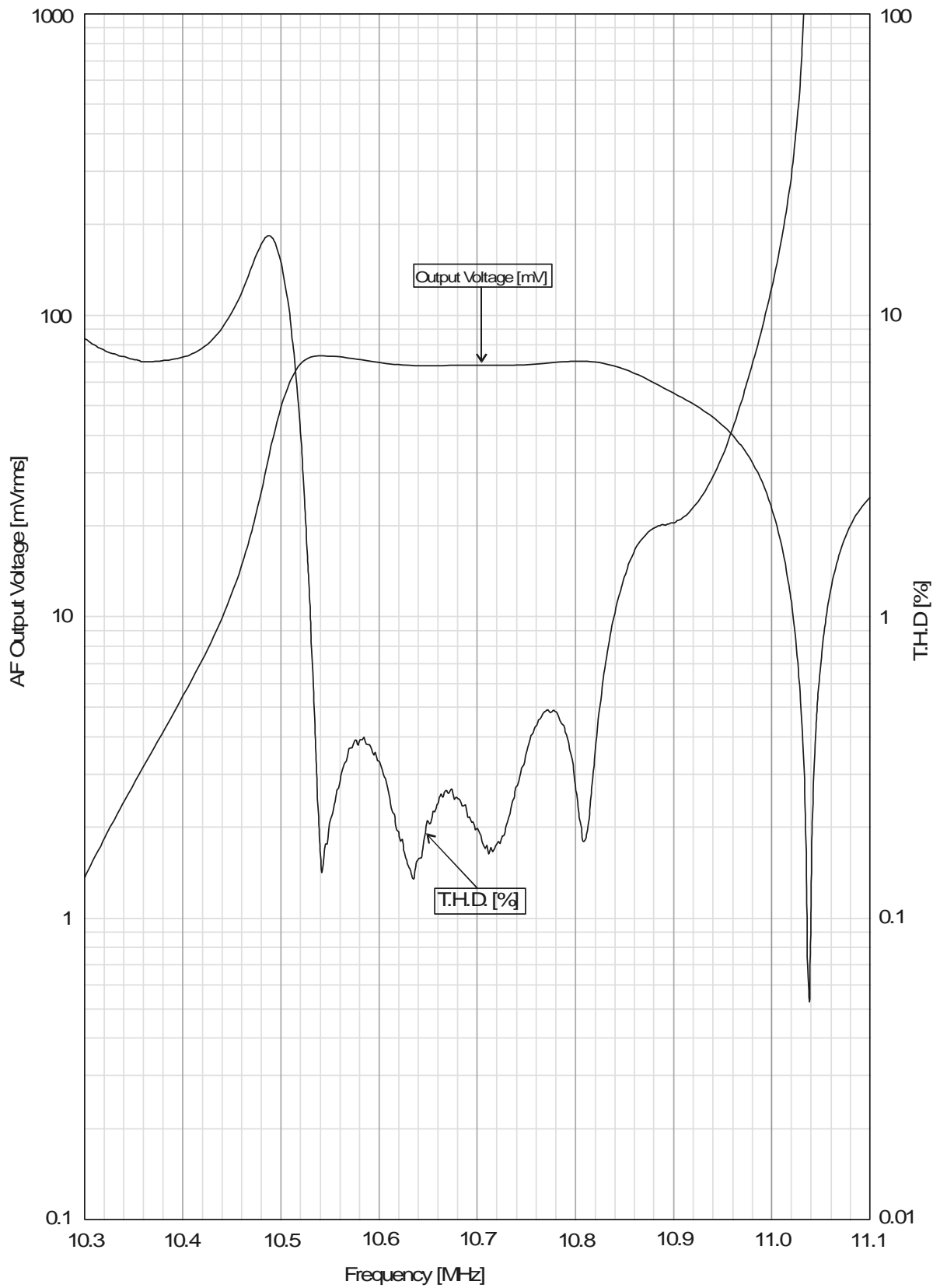


Figure 83: Example of Recovered Audio and Total Harmonic Distortion for Bridge Detection

Applications

IC Characterization Service

The ceramic discriminators produced by Murata may or may not work with all chips using standard external circuit values. This is mainly due to typical variations in IC manufacturer detection circuits, part family to part family or IC maker to IC maker. In order to assist our customers with their designs, Murata offers a chip characterization service free of charge. The chip that our customer is using is tested with the Murata discriminator and the discriminator frequency will be adjusted for the particular IC. Murata provides the engineer the recommended Murata part number that should be used with their target IC and the recommended external hook up circuit for this target IC. This enables the designers to adjust their designs so that the discriminator will work every time. These adjustments can be as simple as adjusting component values or as complicated as redesigning the entire circuit. Murata Electronics sales representatives are able to arrange IC characterizations. Please try to start the IC characterization process with Murata as soon as possible, since it does take time to do an IC characterization and there can be several customers at any one time waiting for this service. Please see Appendix 3 for more information on this service and the needed forms.

Piezoelectric ceramic discriminators are used in the detector stage of receivers. In Figure 84, the detector block is the circuit shown in Figure 64. The output of this circuit would then go to a speaker.

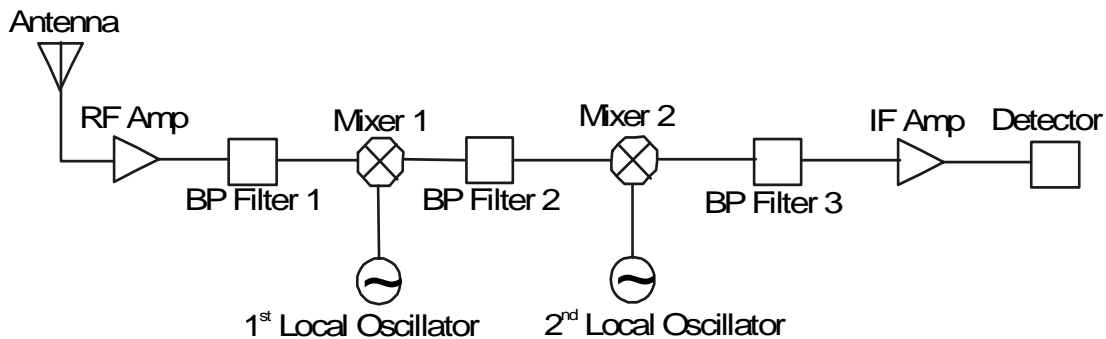


Figure 84: Double Super Heterodyne Receiver

Parts

Figure 85 gives an example of the Murata part numbering system for discriminators.

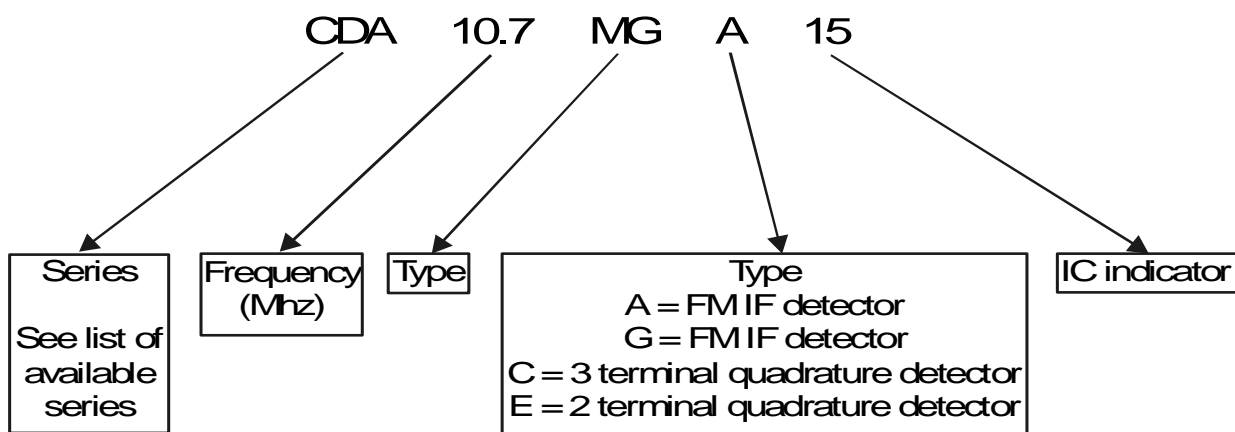


Figure 85: Discriminator Part Numbering System

Table 12 lists the different series of discriminators offered by Murata and gives a brief description of each series. Some older series are shown for reference purposes, so all series with an asterisk (*) are not available for new designs and may be obsolete

Discriminator Series	Description	SMD/Leads
CDA...MG	Wide bandwidth, low recovered audio, 2 terminals	Leads
CDA...MC	Narrow Bandwidth, high recovered audio, 2 terminals	Leads
CDA...MA	3 terminal device	Leads
CDA (4.5-6.5) ME(MD)*	Quadrature detection, 2 terminals	Leads
CDA (4.5-6.5) MC*	Differential Peak detection, 3 terminals	Leads
CDSH(4.5-6.5) ME	Quadrature detection, 2 terminals	Leads
CDSH(4.5-6.5)MD	Differential Peak detection, 2 terminals	Leads
CDSH(4.5-6.5) MC	Quadrature detection, 3 terminals	Leads
CDB...C	kHz discriminator, no series inductor	Leads
CDBM...C	Miniature version of CDB...C	Leads
CDB...CL	Wide bandwidth, used with series inductor	Leads
CDBM...CL	Miniature version of CDB...CL	Leads
CDBC...CX	Not used with series inductor, narrow bandwidth, 2 terminals	SMD
CDBC...CLX	Used with series inductor, wide bandwidth, 2 terminals	SMD
CDBCA*	Surface mount device, 2 terminals + 1 dummy terminal	SMD
CDACV	MHz surface mount discriminator	SMD
CDSCA	MHz surface mount discriminator	SMD

Table 12. Discriminator Series Description

Appendix 5 shows a list of ICs that have been characterized by Murata and the recommended discriminator for each IC.

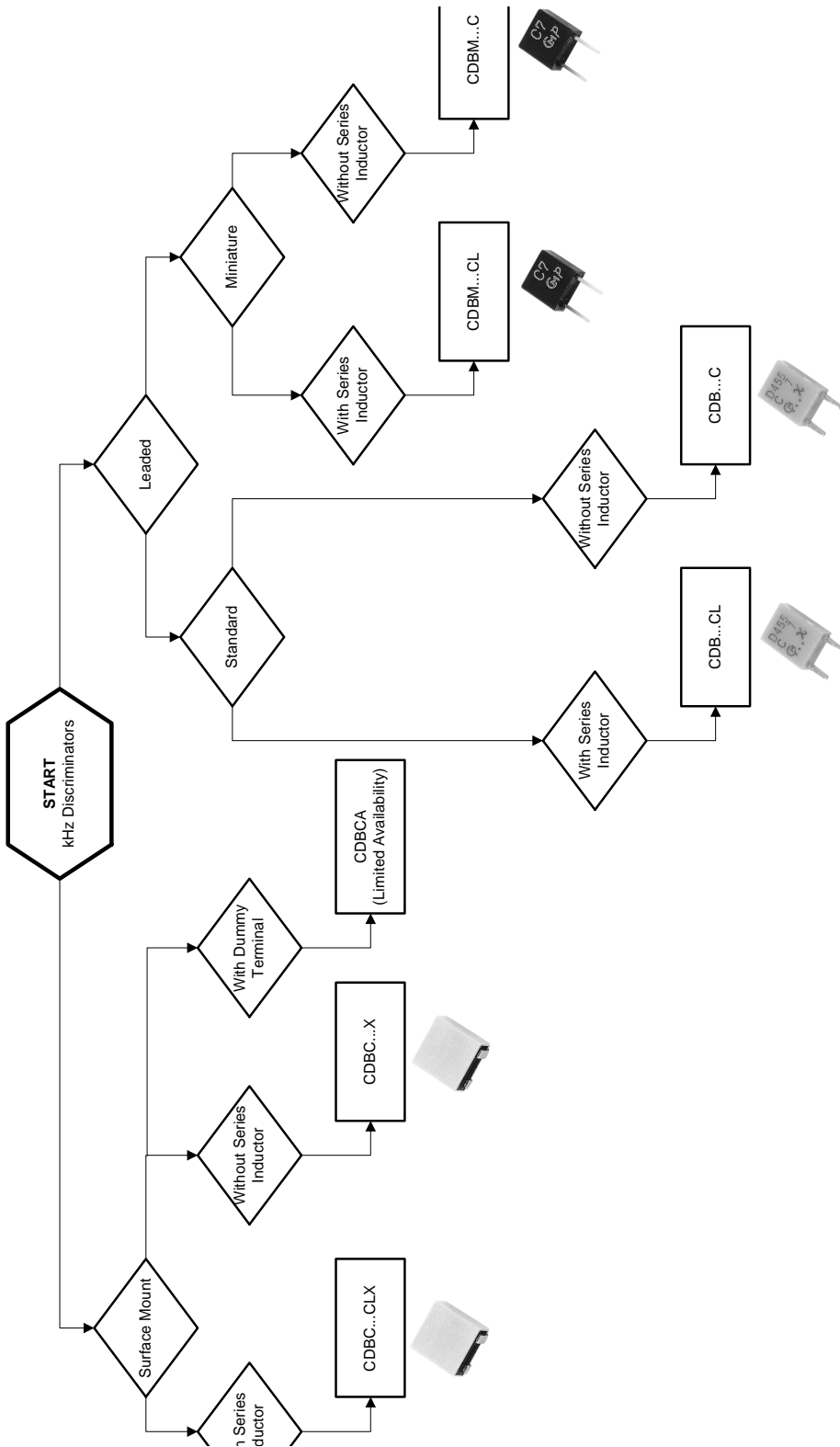


Figure 86: kHz Discriminator Selection Chart

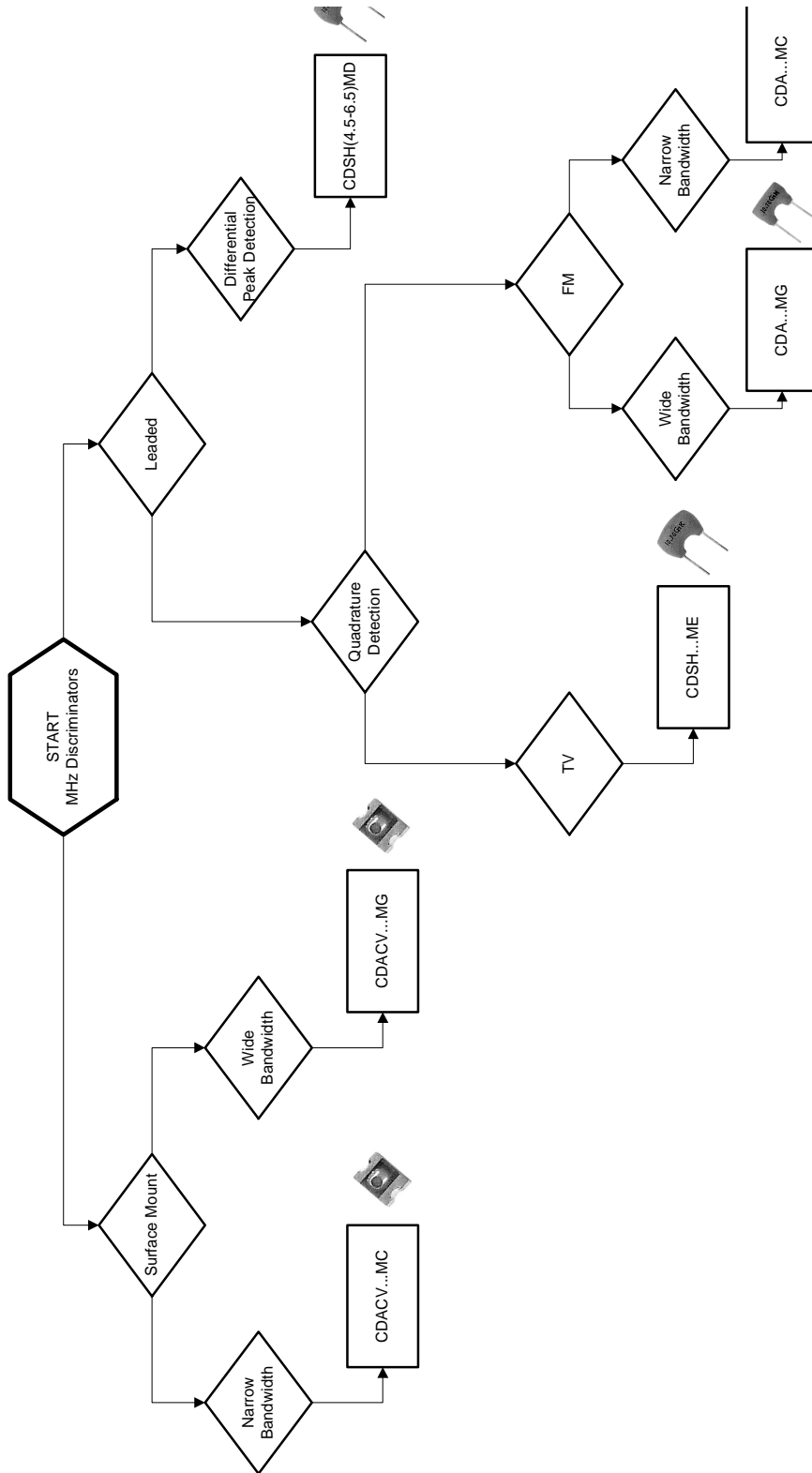


Figure 87: MHz Discriminator Selection Chart