# Low Cost, Triple Balanced, LTCC Mixer

## *Introduction*

Double balanced Mixers are used widely in frequency translation applications. Some of the advantages of the double balanced mixer are good L-R and L-I isolation and moderate R-I isolation. Triple Balanced Mixers (also called Double-doubly balanced mixers) have three separate baluns for LO, RF and IF ports. This structure helps provide wide bandwidth, good L-R, L-I and R-I isolations,VSWR, compression and IP3, all at the expense of 3dB higher RF power . The only disadvantage is the number of components, which results in large size and the complexity, which makes it an expensive design. Mini-Circuits has designed a new LTCC (Low temperature Co-fired Ceramic) based mixer (patent pending) which substantially reduces the size and complexity. It uses combination of LTCC and ferrite based baluns and Schottky diode quads to realize a small, Triple balanced mixer.

## *Operating principle of the Mixer*

Fig 1 shows the schematic of the mixer. It consists of an LO transformer T1, an RF transformer T2 and an IF transformer T3. Transformer T1 is comprised of transmission line transformers T1' and T1''. Similarly, T2 is comprised of T2' and T2''.
Transformer T3 is also a transmission line transformer. Quads QD1 and QD2 are in monolithic form to obtain superior match.
During the positive half cycle of LO, diodes D1, D3, D6 and D8 are on. The resulting polarity of the RF signal at IF port is of a particular polarity. During the negative half cycle of LO, diodes D2, D4, D5 and D7 are on the resulting polarity of the RF signal at IF port is now reversed. This is equivalent to mathematical multiplication or mixing. The result is sum and difference frequency of LO and RF signal. Usually the difference frequency is used as desired IF.
Inter port isolation is achieved due to the balance of the circuit. Referring to fig 1, node 'E' and 'F' are at ground potential for LO signal. Hence LO and IF are isolated.
LO signal from T1 appearing at T2' terminal (so also at T2") is of same polarity and magnitude. Hence, LO and RF ports are isolated from each other.
The RF signal appearing at IF port is switched every half cycle. By fourier analysis, it can be shown that RF signal component is not present at IF.
This inter port isolation is ideal for the usability of the mixer as it eliminates or reduces the need for external filtering.

## *Construction of the LTCC mixer.*

For frequencies below 5 GHz, ferrite based transformers are widely used as baluns. The result is a very manual oriented manufacturing process. This becomes a major handicap for large-scale manufacturing. In this new approach, LTCC( Low Temperature Co-fired Ceramic) has been used as the medium to realize two of the baluns to make it a compact mixer. Quads are used in die form to minimize size and cost. The advantages of the new approach are as follows:

1) Small size: 0.25”x0.3”x0.2”.
2) Reduced manufacturing steps
3) High repeatability due to integrated components
4) Easy to mass produce.
5) Low Cost

Fig 2 shows the photograph of the new mixer.

### *Performance of the mixer:*

Fig 3 shows the conversion loss of the mixer MCA-35LH. Note the conversion is around 6.5 dB over 1800-2500 MHz. This mixer has a typical L-R, L-I and R-I isolation of 30 dB as shown in fig 4. It also has excellent matching on all three ports with the following return losses at:

a) LO port: 12 dB typical
b) RF Port: 10 dB typical
c) IF port: 20 dB to 500 MHz and 10 dB to 1000 MHz

As can be seen, fig 5 shows the return loss of LO, RF and ports and fig 6 that of IF port. Fig 7 shows the IP3 performance. The third order intercept point of this mixer is 16 dBm typically over its entire range. The 1 dB conversion point is typicaly at +16dBm RF input. This mixer has a useable performance over 500 to 3500 MHz.

A second mixer with optimized performance over 3000 to 4500 MHz with an IF BW of 10-1300 MHz with an useable range of 1000 to 5000 MHz has also been designed(Model number MCA-50LH. The above mixers need 10dBm LO power to operate.

### *Conclusion:*

A series of Triple balanced mixers have been designed using LTCC. These mixers, are small in size, have repeatable performance, need less manufacturing steps, and hence lower cost. They are ideal for low, medium and high volume markets as they are easy to reproduce, compared to ferrite based mixers.

## *TABLE 1. ELECTRICAL SPECIFICATIONS   LO=+10 dBm*

| MODEL NO. | FREQUENCY (MHz) LO/RF $f_L$-$f_U$ | FREQUENCY (MHz) IF | CONVERSION LOSS (dB) Typ. | CONVERSION LOSS (dB) σ | CONVERSION LOSS (dB) Max. | L-R ISOLATION (dB) Typ. | L-R ISOLATION (dB) Min. | L-I ISOLATION (dB) Typ. | L-I ISOLATION (dB) Min. | IP3 (dBm) @ CENTER BAND Typ. | E FACTOR | CASE STYLE | PRICE $ QTY. (10-49) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MCA-35LH** | 500-800 | 10-300 | 6.3 | 0.1 | 7.7 | 18 | 11 | 32 | 25 | 16 | 0.6 | DM842 | 6.95 |
| | 800-1000 | 10-200 | 7.1 | 0.1 | 8.6 | 24 | 17 | 30 | 23 | 18 | 0.8 | | |
| | 1000-1800 | 10-800 | 7.3 | 0.1 | 8.9 | 29 | 20 | 28 | 20 | 16 | 0.6 | | |
| | 1800-2000 | 10-200 | 6.3 | 0.1 | 8.2 | 32 | 25 | 30 | 23 | 16 | 0.6 | | |
| | **1800-2500** | **10-700** | **5.8** | **0.1** | **8.2** | **32** | **22** | **30** | **21** | **16** | **0.6** | | |
| | 2000-3500 | 10-1500 | 6.5 | 0.1 | 8.7 | 29 | 17 | 26 | 16 | 17 | 0.6 | | |
| | 500-3500 | 10-1500 | 6.9 | 0.1 | 8.9 | • | | • | | | | | |
| **MCA-50LH** | 1000-1400 | 10-400 | 6.8 | 0.1 | 8.5 | 20 | 11 | 32 | 25 | 17 | 0.7 | DM842 | 7.95 |
| | 1400-2000 | 10-600 | 6.6 | 0.1 | 7.7 | 25 | 20 | 32 | 25 | 17 | 0.7 | | |
| | 2000-2600 | 10-600 | 7.8 | 0.2 | 9.9 | 25 | 18 | 30 | 24 | 18 | 0.8 | | |
| | **2600-4500** | **10-1500** | **7.8** | **0.1** | **8.6** | **35** | **20** | **25** | **15** | **15** | **0.5** | | |
| | 4500-5000 | 50-500 | 8.0 | 0.2 | 9.9 | 35 | 22 | 25 | 15 | 16 | 0.6 | | |
| | 1000-5000 | 10-1500 | 7.3 | 0.2 | 9.9 | • | | • | | | | | |

• See individual band specs.
E-FACTOR= [IP3(dBm)-LO Power(dBm)]/10

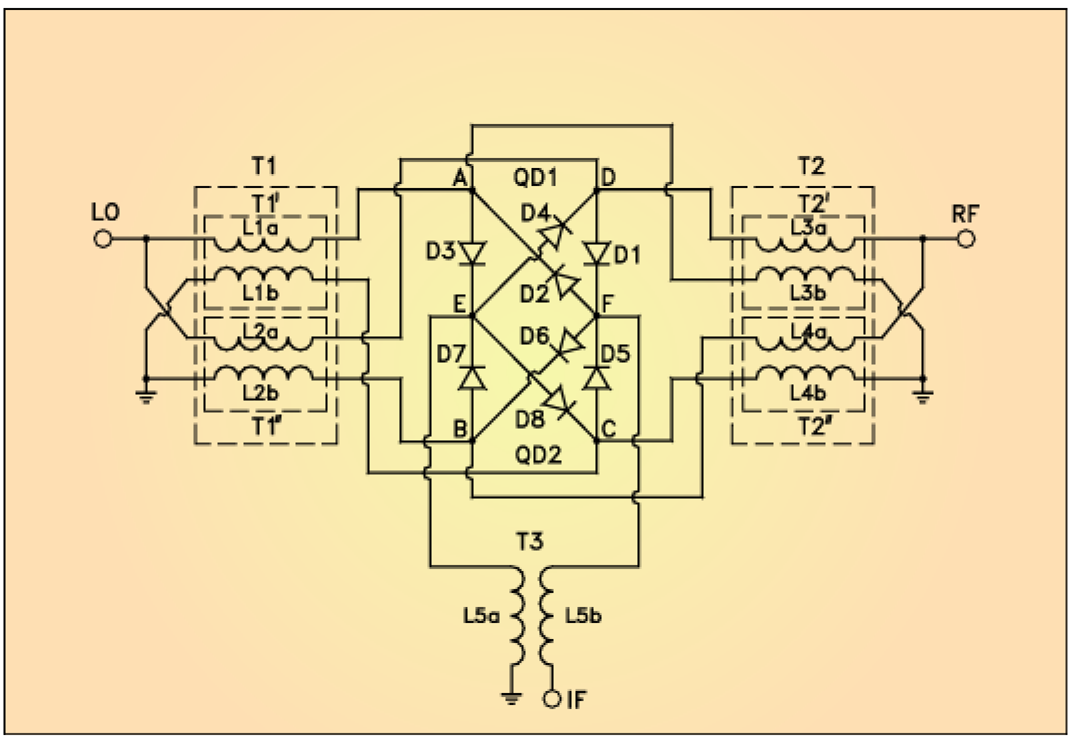


Fig. 1  Schematic of the Mixer

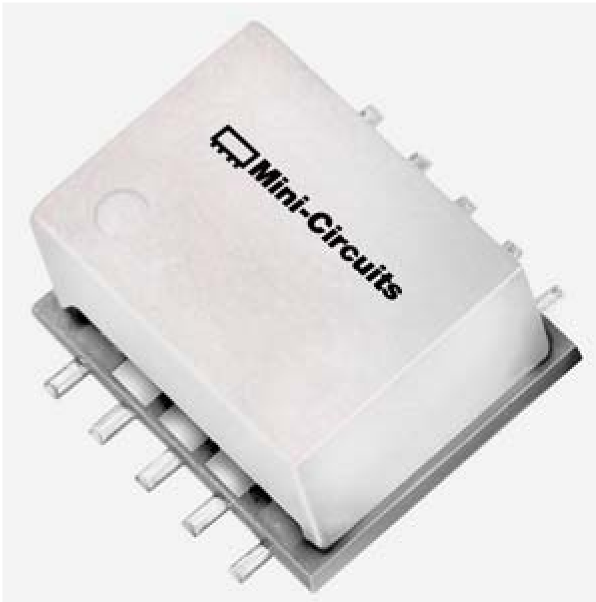


Fig. 2

**Fig.3**
**MCA-35LH**
**CONVERSION LOSS**

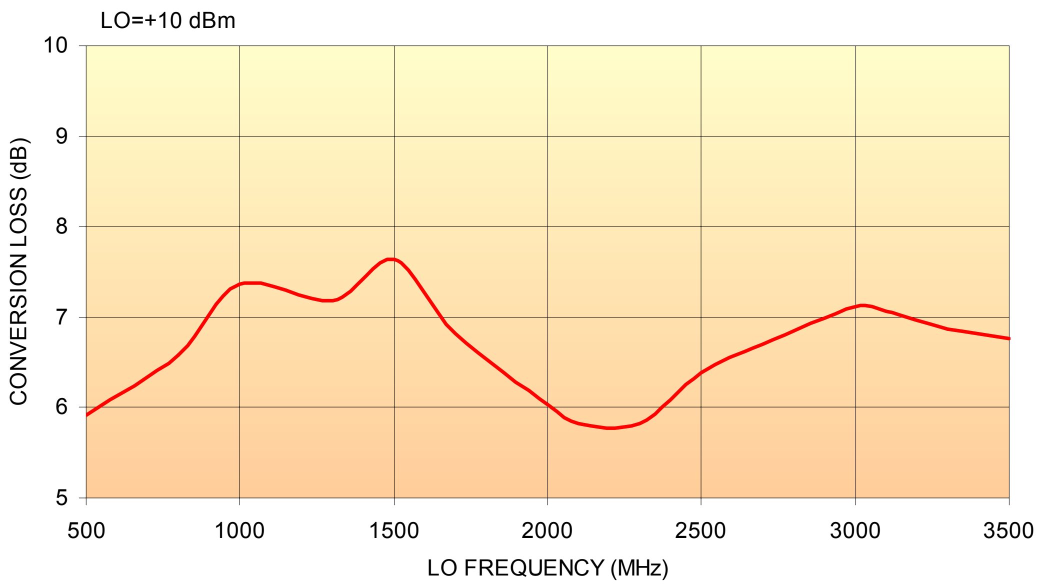

**Fig.4**
**MCA-35LH**
**ISOLATION L-I / L-R / R-I**

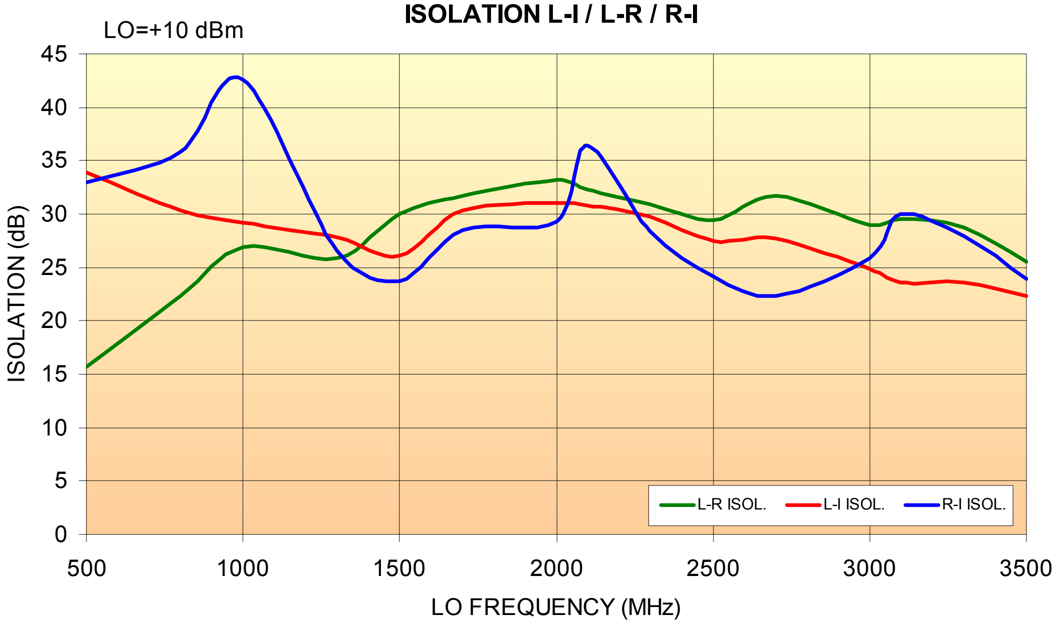


**Fig. 5**
**MCA-35LH**
**LO&RF RETURN LOSS**

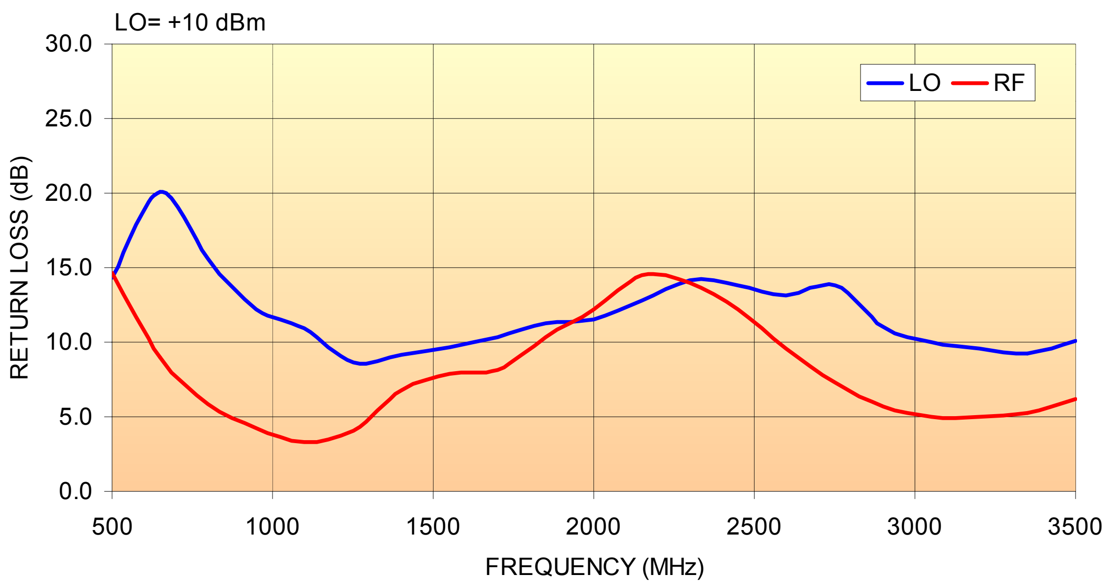

**Fig. 6**
**MCA-35LH**
**IF RETURN LOSS**

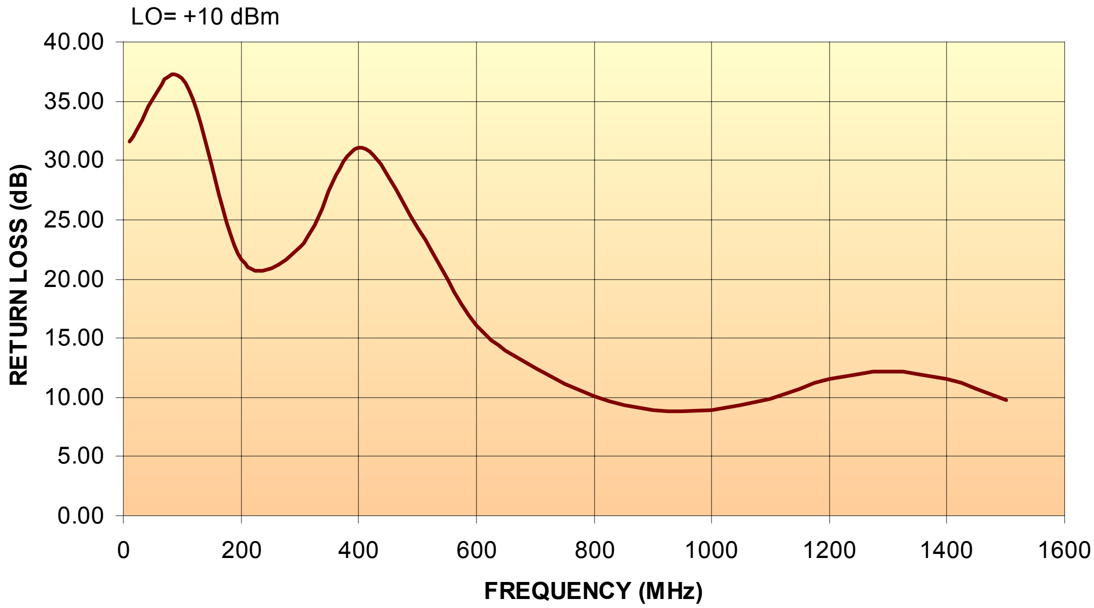


**Fig. 7**
**MCA-35LH**
**IP3**