RF Balun Transformers

M565

V2.00

Introduction

This application note is designed to help the reader understand how balun transformers can be used in today's RF/Microwave communication applications. There is an increasing demand for balun transformers in today's telecommunication market and M/A-COM is leading the field with this device. As many as six of this device can be used around any particular chip as illustrated in figure 4. M/A-COM's balun transformer can be classified into two groups A) The flux coupled balun transformer and B) The transmission line balun transformer.

Definition of Terms

Insertion Loss (dB): Loss due to transmission from primary dot port to secondary dot port and secondary port. Most balun transformers are symmetrical through their central horizontal axis, therefore, an input can be applied at the primary dot port or the primary port with differential outputs at the secondary dot and secondary ports.

Amplitude Balance (dB): Measure of the difference in amplitude between the two differential outputs.

Phase Balance (degrees): Measure of the difference in phase between the two differential outputs, i.e. measured from ±180°.

Return Loss (dB): Loss due to reflection at any port.

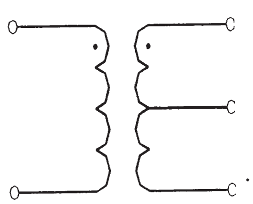

Figure 1. Flux Coupled Balun Transformer

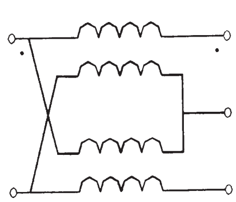

Figure 2. 4:1 Transmission Line Balun Transformer

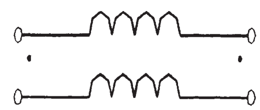

Figure 3. 1:1 Transmission Line Balun Transformer

A. Flux Coupled Balun Transformers

The flux coupled balun transformer can provide a wide range of impedance ratios; 1:1, 4:1, 9:1 and 16:1 are most common. DC isolation from primary coil to secondary coil is also a feature of this device. It has a low loss and good balance over a broad frequency bandwidth. The ETC4-1-2 has an insertion loss of approximately 2.5 dB at 800 MHz and is an example of one of our most popular flux coupled balun transformers.

B. Transmission Line Balun Transformers

The transmission line balun transformer comes in two impedance ratios as outlined above, i.e. 4:1 and 1:1. It operates at higher frequencies and over a greater bandwidth than the flux coupled balun transformer. It cannot provide DC isolation from primary side to secondary side. The ETC1.6-4-2-3 is an example of one of our most popular 4:1 transmission line balun transformers with an optimum performance of 1 dB insertion loss at 900 MHz.

Applications

The applications of these devices are:

1. Impedance matching

See figure 5. The inputs to the LO buffer amplifier and the quad diode ring are at 100 W approximately.

2. DC isolation

See figure 5. At DC there is no magnetic coupling, therefore, the LO balun transformer and the RF balun transformer are acting as open circuits at DC.

3. Matching balanced ports to a single ended port

See figure 6. The inputs to the diode pair are 180° out of phase.

The flux coupled balun transformer can incorporate all of the above, whereas the transmission line balun transformer cannot provide DC isolation. Matching single ended ports to balanced (differential) ports on an integrated circuit is a common application of these devices. Figure 4 shows the first mixer stage and second mixer stage of a receiver chip functional block diagram that is commonly used in digital radio applications.

Here are the differential ports associated with the chip in figure 4;

- Differential outputs from second local oscillator buffer amplifier 1

  +LOB1
  –LOB1

- Second local oscillator differential inputs

  +2LOIN
  –2LOIN

- Differential IF inputs

  +IFIN
  –IFIN

- Differential outputs from first mixer

  +MXOUT
  –MXOUT

- Differential inputs to first mixer

  +MXIN
  –MXIN

- Differential inputs to first local oscillator

  +1LOIN
  –1LOIN

- Differential outputs from second local oscillator buffer amplifier 2

  +LOB2
  –LOB2

"Passive matching" refers to the use of a ferrite wound transformer "off chip" to do this job, while "active matching" incorporates the transformer (or matching device) on the chip. The advantage of active matching is that there is a cost reduction due to the absence of the ferrite wound transformers, but the chip then becomes very specific, also the quality of this matching will not be as good as the matching that a passive transformer would provide. Passive matching allows the design engineer to design a chip that could cover more than one application, i.e. his design is more versatile.

Also, matching at IF frequencies for GSM, for DCS, PCS and WLAN, for example, can be extremely awkward without using low loss, broadband transformers. Examples of the differential ports that would need to be matched to a single ended port are the differential outputs of a diode quad ring, a Gilbert cell or a FET quad. At RF frequencies for GSM, WLAN, DCS and PCS

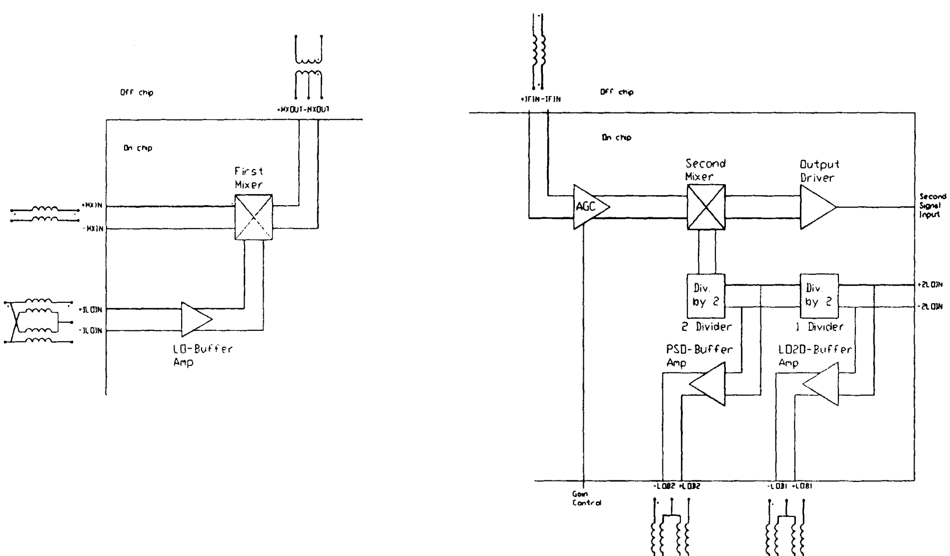

Figure 4. First Mixer Stage and Second Mixer Stage of a Single-chip Double-conversion Heterodyne Receiver Commonly Used For Digital Mobile Telephones According to the GSM Standard and Other Digital Systems. Shows Where Six Balun Transformers Can Be Used

systems, ferrite wound balun transformers are commonly used for matching these differential ports to single ended ports.

As well as matching the balanced ports to the single ended ports, the transformer may also be required to match two different impedances. The impedance of the balanced ports of a quad diode ring is commonly 100 Ω, the impedance of the balanced ports of a Gilbert cell is higher than this. A 4:1 balun transformer operating in a 50 Ω environment will present 100 Ω at both outputs of the device. M/A-COM's RF balun transformers are excellent components for fulfilling both of these functions.

Although all of these differential ports do not need to be matched to single ended ports by transformers, (some of these differential ports would be linked to other differential ports in the circuit and others may not be driven as differential ports) there are applications for balun transformers at the IF, LO and RF differential ports on receiver chips such as this one.

In his application, the design engineer may require differential to single ended matching at the inputs to the first mixer, i.e. ±MXIN, he may also want to do the same at the input to the first local oscillator, i.e. ±1LOIN and at the differential outputs of the second local oscillator buffer amplifiers, i.e. ±LOB1 and ±LOB2. The design engineer may also use balun transformers at the IF output of the first mixer and the IF input to the second mixer i.e,. ±MXOUT and ±IFIN.

Flux coupled transformers are commonly used for IF applications while transmission line transformers are used for RF and LO applications. However this is a guideline and is not true in all cases.

Some common applications of M/A-COM transformers are:

1. Flux coupled balun transformer on miniature ceramic carrier. Impedance matching two balanced outputs from a diode quad ring for a mixer, to a single ended IF output on a down converter chip for digital radio applications. The input impedance is 50 Ω and the output impedances are 100 Ω. Examples: ETC4-1-2, ETC4-1, ETC4-1T-3.

2. Flux coupled balun transformer on a miniature ceramic carrier. Impedance matching single ended IF input to differential IF ports for digital radio applications. The input impedance is 50 Ω and the output impedances are 75 Ω. Example: ET3-1T-3.

3. 1:1 transmission line balun transformer on miniature ceramic carrier. Matching two differential RF ports to a single ended RF port for digital radio applications, 800 – 1000 MHz. The input impedance is 50 Ω and the output impedances are 25 Ω when operating in a 50 Ω environment. Examples: ETC1-1-13, ETC1-1-6.

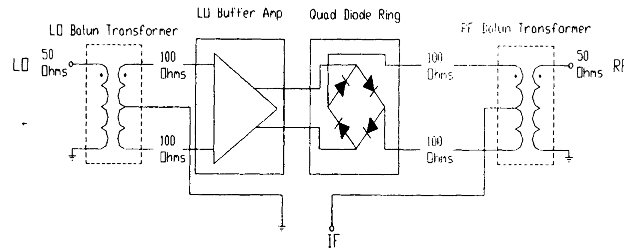

Figure 5. Double Balanced Mixer Using Two 4:1 Flux Coupled Balun Transformers

4. 1:1 transmission line balun transformer on miniature ceramic carrier. Matching two differential RF ports to a single ended RF port for digital radio applications, 1500 – 2000 MHz. The input impedance is 50 Ω and the output impedances are 25 Ω when operating in a 50 Ω environment. Examples: ETC1-1-13, ETC1-1-10.

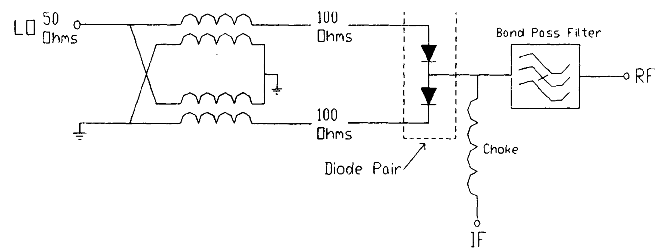

Figure 6. Single Balanced Mixer Using One 4:1 Transmission Line Transformer

5. 4:1 transmission line balun transformer on miniature ceramic carrier. Impedance matching single ended LO input to differential inputs of a diode pair for a front end single balanced mixer application for digital radio applications. The input impedance is 50 Ω and the output impedances are 100 Ω. Examples: ETC1.6-4-2-3, ETC4-1T-6, ETC1.6-4-2-4, ETC4-1T-7.

6. 1:1 transmission line balun transformer, 0.5 to 700 MHz. Matching differential twisted wire pair to a single ended coaxial cable for a digital distribution board in a telephone exchange, therefore, the device operates as an interface between a twisted wire pair and a coaxial cable.

The input impedance is 75 Ω and the output impedances are 37.5 Ω when operating in a 75 Ω environment. Example: ETC1-1-75.

7. 4:1 flux coupled unbalanced to unbalanced transformer that provides a 50 Ω to 200 Ω impedance match and DC isolation for a CATV application. 3 dB Bandwidth = 0.2 to 350 MHz. Example: ET4-1.

Figure 5 shows two flux coupled 4:1 balun transformers being used in a double balanced mixer application.

Figure 6 shows one flux coupled 4:1 balun transformer being used in a single balanced mixer application.

Conclusion

M/A-COM has designed, a wide range of RF/IF transformers to suit today's most advanced telecommunication applications. The product range is comprise of over 100 standard products across a frequency bandwidth of 3 kHz to 3 GHz. The M/A-COM transformer design team will also work closely with system design engineers to meet their specifications.

Since we combine proven technological expertise with innovative high quality and low cost manufacturing capabilities, M/A-COM is the technological partner of choice for the world's most competitive companies.

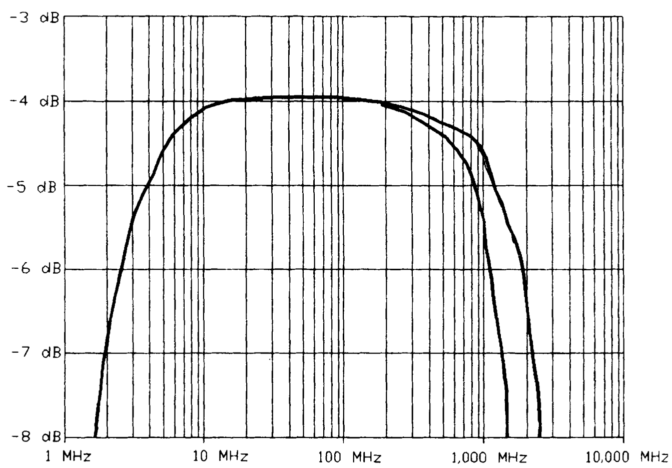

Figure 7: Insertion Loss Cure of a 4:1 Flux Coupled Transformer.