LVDS - twisted pairs representation in PCB tracking.

Flex PCBs were developed some fifty years ago specifically to replace cables – or electrical wiring interconnect systems – in order to save weight, to save space and to improve performance. In spite of the multiple benefits provided by flex, twisted pair cable remains the incumbent technology.

With the development of advanced flex PCB manufacturing solutions, such as provided by Trackwise' Improved Harness Technology, www.trackwise.co.uk, it is worth re-examining the comparative benefits of flex PCB and twisted pair cable, specifically with regard to data cabling for high speed, low noise applications.

It has always been the case that whenever one wished to create low noise, high immunity cables, the standard approach was to use good grade cables, where the conductors are twisted at roughly 5 to 8 twists per inch and if budgets and weights permitting a good quality ground or Logic 0 screen.

a) Selecting high silver content, multi stranded low loss cable is always a good if expensive starting point.
b) The number of twists per inch is determined by the Physical and Electromagnetic environment, type of signal utilised and the speed of transmission.
c) The Electromagnetic environment will in many ways determine the physical construction of any good quality cable. It will often determine the number of screens and the density of the mesh thickness.
d) The Physical environment will determine the type and thickness of any overall coverings as well as cable restraints and back shells or covers.
e) LVDS (Low Voltage Differential) signals by their very nature are more susceptible to any form of Electromagnetic interference and signal integrity reduction due to DC resistance losses as well as AC reactive losses.
f) Controlling the Characteristic impedance so that the Characteristic impedance of driver, cable and receiver ensure minimal impedance mismatch and hence reduce losses and signal reflections.

So with all this good information how do we migrate the same electrical and physical requirements into a PCB or Flexi circuit and what other benefits will ensue from such a transformation?

We have to look at all the above factors and try to understand exactly what physical and electromagnetic parameters we are looking to control.

In point a);

We are looking to create as low an electrical impedance as possible in order to reduce heat losses and loss of signal integrity as well as ensuring that the cable has the correct safety and current carrying capabilities required for the application.

In the field of PCB and Flex circuits these factors are addressed by different approaches to that of a cable. Firstly the low electrical impedance requirements determine the "weight" (or thickness) of the tracks in the PCB, It will also determine the width of the tracks, as well as the number of tracks used and in the case of multilayer circuits on how many layers the signal track appears. For high current applications it common to use a single layer to carry the total currant required. This is achieved by using a flooded plane of reasonable weight copper. Flooded planes also have significant benefits for overcoming some of the electromagnetic issues.

In point b);

What are we achieving by twisting the conductors? When we are utilising a differential pair of conductors (One is a Positive signal, the other Negative Signal). These are subtracted from the other at the receiving (Rx) device. By virtue of the twisting of the conductors signal noise should be induced in both conductors equally, and so can be removed by the subtraction process.

In the PCB and Flex arrangement we achieve this result via a different process. We make use of ground or power planes either to one side of a signal pair, (Microstrip) or a ground or power plane above and below the signal pair, (Stripline) We then ensure the geometrical placement of the conductor pairs fit into a few simple guide rules.

> The distance between to conductors of any one pair (S) should be less than the width (W) of the conductors, which should always be the same width.
>
> The distance from one differential pair to another should be at least twice (S) or (W)
>
> The distance from the ground or power lane above the signal pair to the ground or power plane below the signal pair should be greater than (S).

If these rules are met then, due to the continuous nature and consistency of the printed flex ground plane geometry, the differential pair will receive far less signal interference from the external environment. In a similar manner, due to the precision and consistency of the printed flex geometry both signal conductors will have more precisely the same noise floor, subtracted in the same way as above to leave a lower noise signal. By contrast to the twisted pair, where variations in twist, particularly after movement, means that the pair geometry or screen separation cannot be guaranteed in the same manner.

Limiting the effects of the electromagnetic environment (point c) in a PCB or Flex arrangement is a simpler issue than a physical cable. When using ground or power planes it is far easier to make a complete and effective screen over the entire length and width of the assembly. Cables are always prone to screens not being complete and are prone to gaps or holes appearing in the braid after a period of time.

Ensuring adequate physical protection to a PCB or Flex circuit (point d) is also simpler than a physical cable. Use of conformal coating, plastic or silicon resins, varnishes or simply solder resist are all simple processes to apply to a PCB or Flex circuit, and as Flex circuits are invariably far lighter than their cable counterpart, (approximately a factor of 4 times lighter for a typical flex assembly) they will be subjected to far lower shock and vibration forces.

In order to create the best conditions for LVD Signals (point e) in keeping to the guide rules above for twisted pairs, coupled with a far tighter control of the signal pair characteristic impedance (point f) and minimising right angled traces, (in tracks and by avoiding via holes) and avoiding un-terminated stubs, we find that LVDs signals in a PCB or flexi circuit are inherently more stable and reproducible than in a cable.

Due to familiarity with twisted pairs and lack of understanding of flex PCB performance, there has been the suggestion to represent cable twisted pairs in flex PCBs by means of looped tracks and multiple vias. This is perhaps acceptable for low data speeds but fundamentally incorrect – and quite unnecessary - for high speed.

When considering characteristic impedance in a PCB or Flex circuit the designer has far more scope to specify any number of dielectric materials as well as copper weights and track and gap dimensions, interlayer spacing etc. this, coupled with the use of ground and power planes that are well populated with both high speed and slow bulk decoupling capacitors ensure a balanced and contiguous distributed controlled impedance over the full length of the LVDs pair. A PCB or Flex circuit also has the added advantage of being able to use several different characteristic impedances within the same assembly, 100 Ohms, 50 Ohms or 78 Ohms for example.

In essence we need to look at the electrical parameters found in a screened twisted pair cable assembly and then look to create the same electrical effect by different means. So whilst both technologies create the desired end result. The processes required in a PCB or flex circuit are completely different.

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