High Frequency Cable Solutions

Introduction

The FE(H)389TA high speed transducer amplifier has a bandwidth of 2MHz with common mode rejection of over 100dB @400Hz. However, for higher frequency vibration, shock or transient testing over long cables the quality (e.g. impedance and capacitance) and length of the transmission media have a significant impact on the overall performance of the card and can cause problems. This is due to the fact that at high frequencies any wiring used to connect the bridge to amplifier actually forms a filter, schematically can be represented by a series of capacitors, resistors and inductances spread across the whole wire. Incorrectly wiring can result in the bridge being unbalanced and these effect are more significant the longer the wiring is.

The purpose of this application note is to help designers find an appropriate cable solutions suited to their needs to use with the FE(H)389TA in order to get the best performance possible. Tests were carried out to compare the **BW** and **CMR** of the FE(H)389TA card using different types of cables in varying lengths.

Bandwidth (BW) is the total range of frequency a signal can be passed without distortion or loss of data. The BW can be calculated if the characteristics of the cable is known using the formula (1) below where f_c is the cut-off frequency in Hz at -3dB attenuation. Note that the line resistance and the inductance is usually negligible in practice and in tests carried out by Fylde Electronic Laboratories the actual BW was approximately 1.5 times better than the calculated one since the capacitance and impedance of the system is spread across a larger area.

$$f_c = \frac{1}{2\pi RC} \qquad (1)$$

Common mode rejection (CMR) indicates the ability of the amplifier card to suppress unwanted signals common to the inputs. These signals could be noise, outside interferences or feedback current. FE(H)389TA amplifier card has a CMR of:
L.F. >110dB @ 50Hz >100dB @ 400Hz H.F. >40dB @ 1MHz

Cable Selection

There are many criteria in determining an appropriate cable such as the required BW, CMR and crosstalk levels and parameters such as conductor resistance, impedance matching, capacitance to GND and between lines can effect the signal quality and the signal to noise ratio (SNR). Therefore, there are many standards regarding the types of cables available such as Electronic Industries Alliance (**EIA**) and the Telecommunications Industry Association (**TIA**).

Conductor Type

For the choice of conductor core, ideally a permanent **solid core** wiring is preferred over **stranded core** as it has lower electrical resistance hence usable for longer distances. The stranded core compared to solid core is more flexible and suitable for an environment with frequent flexing and vibration.

Additionally for noise immunity, the industry standards require cables to be **Shielded Twisted Pair (STP)**. **Twisted Pair** is a type of communications wiring where two identical conductors with similar capacitance and inductance are tightly twisted together to reduce interference from electromagnetic induction. This is normally preferred for balanced (or differential) signals as any distortion to the conductors will be reduced and cancelled out by the differential amplifier and gives a better impedance balance between the two signals. **Impedance matching** is an important part of driving long cables as the cable's characteristics impedance (Z_0) needs to match the system's impedance in order to efficiently transfer signals from transducer bridge to the amplifier and avoid any nasty signal reflections which may cause a lower SNR and peaking at certain frequencies.

Shielded Twisted Pair (STP) Electrical Screening

In regards to cable isolation from environment a PVC insulated sheath, double shielded cable with both PE taped and braided (or foiled) screening will be sufficient protection for a STP.

Most Shielded Twisted Pair (STP) cables are suitable for common 120Ω bridges since they typically have a characteristic impedance Z_0 of 110Ω giving you the full bandwidth range (2MHz) of the system up to 25m however, the C.M.R can differ based on the way conductors were paired, wired and the insulation in between which can form a capacitance imbalance. The parasitics effects introduced by the wires can cause the C.M.R performance to drop by more than 10dB and some STP can have a capacitance imbalance of more than 4%.

Performance

The FE(H)389TA amplifier card features many selectable filter options and can work as a high speed amplifier. This is done by selecting the 'out' filter option giving you an excellent BW of over 2MHz. However, cables are not perfect as they have resistive, capacitive and inductive load and its additive nature means as the cable gets longer the more significant its impacts are on the signal. Also the impedance of the transducer bridge will cause the cable to behave like a filter and attenuate signals at high frequencies therefore effecting the BW of the input. If you are looking to use the amplifier to its full bandwidth choosing the right type and length of cable is critical. Graph below shows an example on using a generic **STP**[1] of 10m against a 50m one with an input impedances of 100Ω.

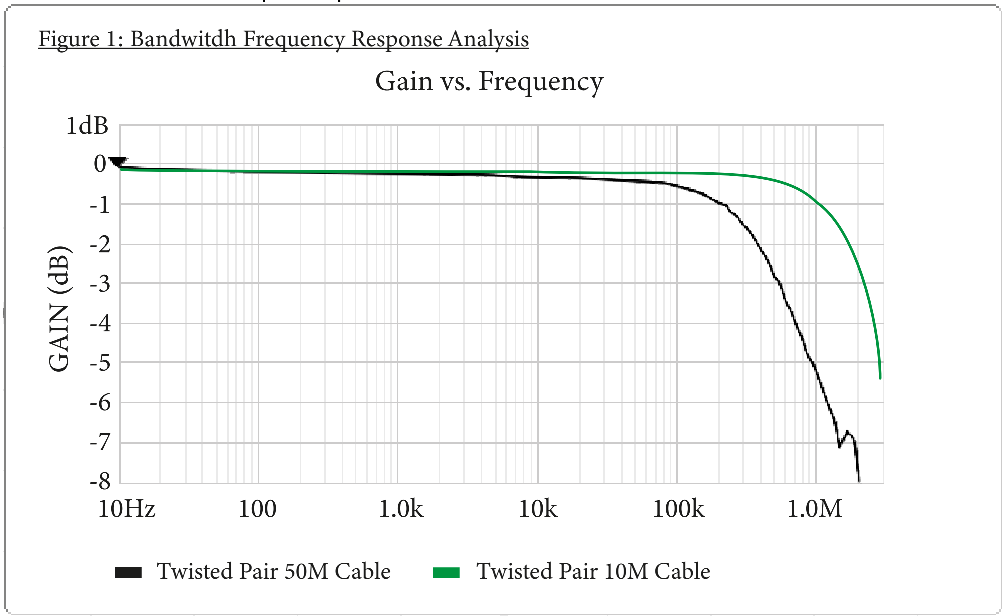
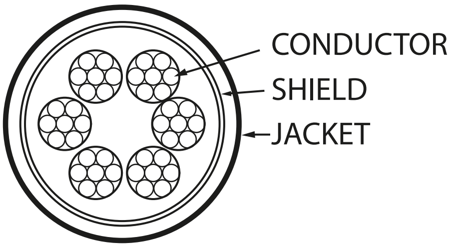


Figure 1. Measured gain versus frequency graph ("Bode plot") for comparing a 10 meters cable against a 50 meters.

STP cable, with characteristic impedances Z_0 of 110Ω, at longer distances can cause coupling between the common mode because of differences of two conductors, capacitive loading causing distortion and filter higher frequency signal, hence the BW range to drop to approx 530KHz from 2MHz (CMR -49dB).

In single-ended and differential signals, unbalanced cables such as: **Screened Multi-Core 7-1-6C Twisted Wire**[2] 6-Cores from Multicomp-Pro 2MHz BW up to 25m,
Capacitance core to screen of 141 pF/m with 1.2% imbalance between the cores.
Conductor resistance of 7/0.1 mm : 384Ω/km, 7/0.2 mm: 92Ω/km.



Is adequate at short distances, providing the full 2MHz bandwidth up to 25m and measured CMR of >47dB @2MHz & 10m. With any longer cable the performance will be impaired and it is not recommended. In multi-

[1] Mfr. Part No.: 860160 50M.

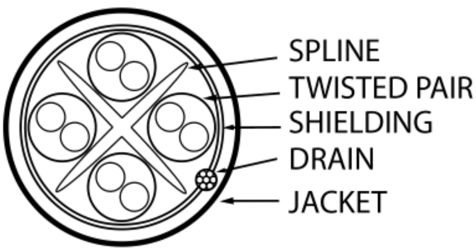
[2] Mfr. Part No.: MP002349

pair wires ideally the signal pairs should be symmetrical and away from any other conductor that might be noisy e.g. bridge volts hence, it is recommended to run the data through a specialised **low capacitance and balanced** cable whilst the bridge volt is routed through a different set of cable to avoid crosstalk and maintain a low capacitance on the data pair. Such as:
Van Damme Microphone Cable[3] 2-Cores braided screened twisted pair balance patch and 2MHz @35m, Capacitance core to screen of 95 pF/m with 0.5% imbalance between the cores.
Conductor resistance of 85 Ω/km. $Z_0 : 110\Omega \ \pm 20\%$.

These type of cables are more expensive but designed to have low capacitances and with the tightly packed cotton fillers it ensures no static or capacitance build up. The twisted pair in the cable have closely match capacitance 95pF/m core to screen, 50 pF/m core to core and with only 0.5% capacitance imbalance making them suitable for longer distances of approximately 35 meters whilst providing a 2MHz bandwidth with a CMR performance of -60.5dB @2MHz & 10m.

Recommendation
RS485 Cable[4] 4-Cores screened multi-pair low capacitance has an approximate BW of 2MHz up to 30m, Capacitance core to screen of 125 pF/m with <0.16% imbalance between the cores.
Conductor resistance of 86.2 Ω/km. $Z_0 : 100\Omega$.

In order to reduce crosstalk and noise among twisted pairs, some cables are equipped with an insulator (called Spline) to create a gap between each pair and the cable's shielding.
CAT6[5] 8-Cores External Shielded Ethernet Cable FTP with 2MHz BW covering 40m length,
Capacitance core to screen of 67 pF/m with 0.3% imbalance between the cores.
Conductor resistance of 68 Ω/km. $Z_0 : 100\Omega$.



As an example, a 40m long CAT6 cable will have a CMRR performance of > -52dB @2MHz when used with FE(H)389TA high speed transducer amplifier. The graph below compares the CMRR between a matched low capacitance cable CAT6 (blue) against a generic STP cable (black). The difference is apparent as the balanced cable is performing significantly better than the generic STP by a ratio of more than 10dB. Meaning the CAT6's CMR is 3 times quieter than the other cable at 2MHz.

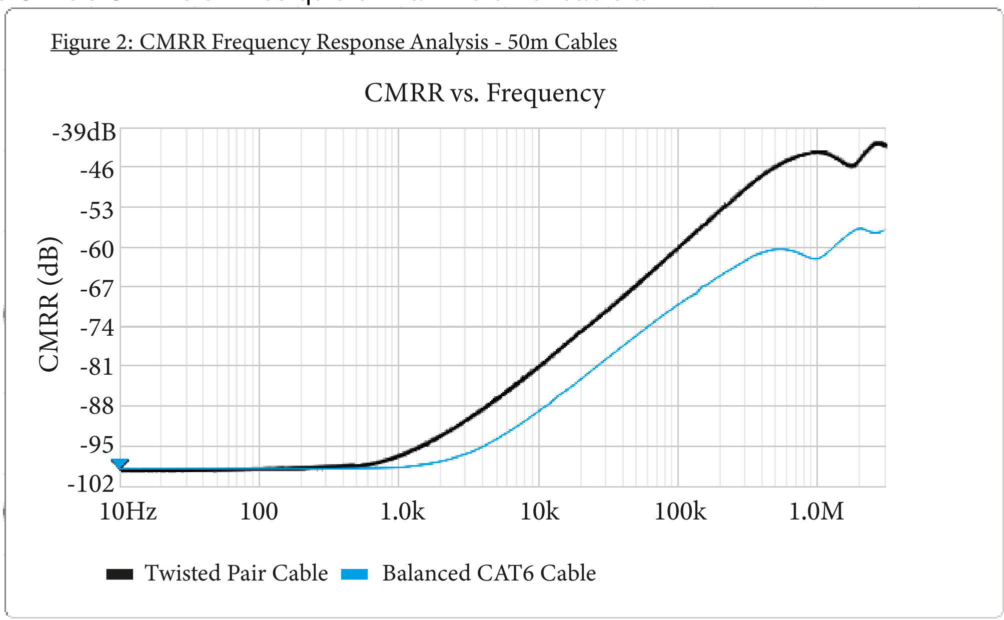


Figure 2. Comparing the performance of a STP cable against a balanced CAT6 cable.

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[3] Mfr. Part No.: 268-009-020.

[4] Mfr. Part No.: PP001165

[5] Model: 6FO-008544

Optional Available Feature For CMR Improvements

Tuner Box
To obtain optimal CMR performance, a 'Tuner Box' can be purchased which you can trim to adjust the capacitance on one end of the cable in order to match and balance both conductors giving you an approximate -10dB improvement as long as the cable configuration is not too unbalanced.

An example of how the Tuner Box can be used to suppress noise common to the inputs by a factor of 3 (-10dB) @2MHz is shown in the graph below.

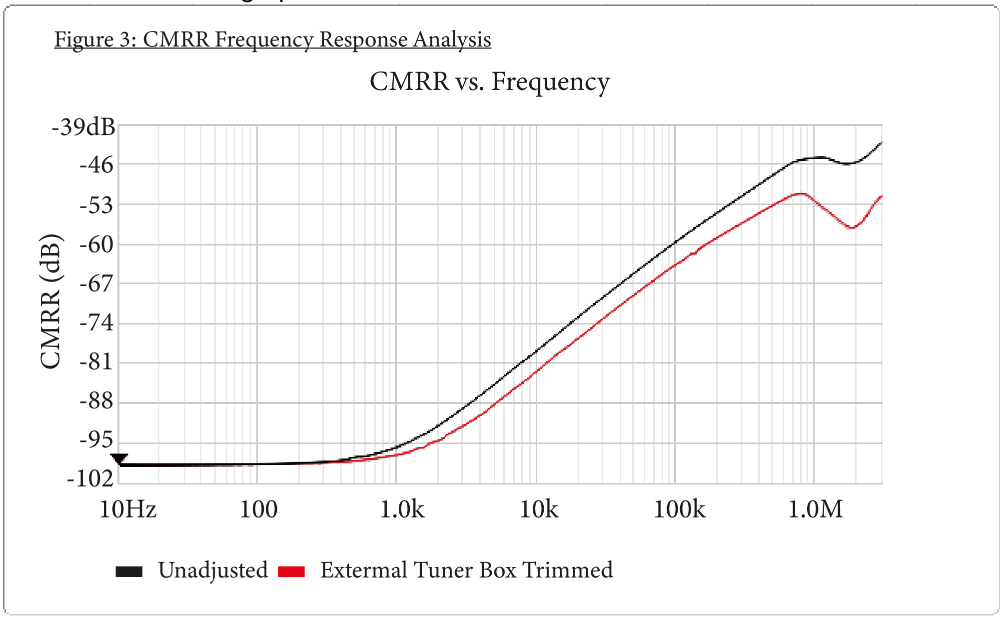

Figure 3. Comparison between an externally trimmed STP cable (red line) using a Tuner Box against an unadjusted one (black line).

Summary

There are basic attributes that each engineer needs to consider; distance, flexibility, environment and SNR. Preferably the transducer wire length to amplifier should be kept to a minimum otherwise, you need to ensure that you are using a balanced connections throughout your system.

In case longer cables are required the capacitance coupling of core to screen should be fairly low with core-to-core capacitance matched, typically lower than 0.3% imbalance. Also the characteristic impedance of the cable should closely match the transducer's impedance and with proper shielding that offers the best immunity from outside noise sources (e.g. signal reflections and crosstalk), it is possible to have a stable and efficient system.