Twisted Pair Tutorial: Using FTT-10A Transceivers

- Introduction
- General PCB Layout Considerations
- Avoiding Magnetic Field Interference
- Physical Layer Repeaters
- Using Category 5 Wire
- General Network Cable Considerations
- IEC 1000-4-6 Conducted RF Susceptibility
- Some Troubleshooting Tips

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Introduction

- The FTT-10A Transceiver is Echelon's most popular transceiver

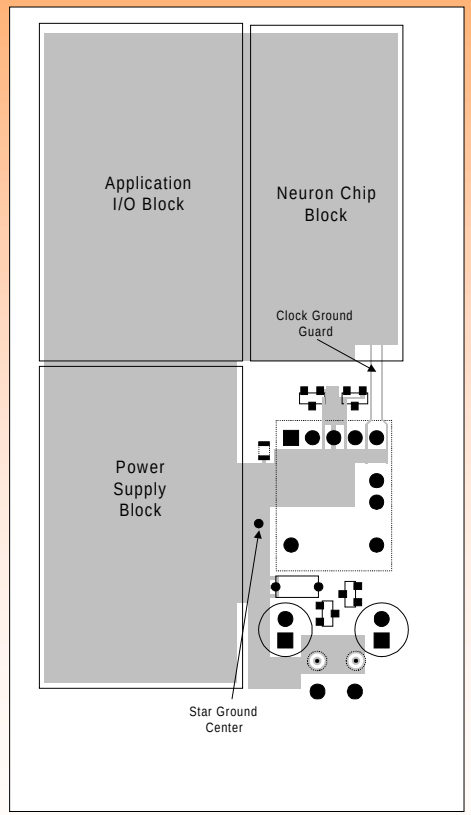
  ≥ 90% of new design wins are with the FTT-10A transceiver
- Echelon offers free design reviews for products with Echelon OEM content (like Echelon transceivers, modules, etc.)
  - All customer documentation is kept confidential, and the information can be returned to the customer or destroyed after the review is complete
  - The best time for a design review on a new product is when you have a schematic, BOM and preliminary PCB layout
  - Contact your sales person, FAE, or Echelon Technical Support for details

FTT-10A Node Design Reviews: Most Frequently-Made Errors

- Frequent errors in PCB floorplan & layout:
  - No star ground configuration, and no explicit ESD exit path
  - Insufficient grounding and decoupling of the Neuron chip & memory circuit
  - The transceiver's ground is too far from the center of the star ground and the chassis ground connection
  - Logic traces are run through the "ESD Keepout" area of the transceiver
- Frequent schematic errors:
  - The LVI circuit is incorrect, or the wrong LVI part is shown
    - The FTT-10A transceiver does not require an LVI, but the Neuron chip or memory circuit may
    - The LVI circuit must be open-collector (many LVIs are not)
  - The memory interface circuit is incorrect or too slow
    - See Echelon's *Neuron® 3150® Chip External Memory Interface* bulletin

General PCB Layout Considerations

- A "Star Ground" Layout is very important for good ESD/EMC performance



  - See the *FTT-10A Free Topology Transceiver User's Guide* for a more complete discussion
  - Place all connectors near the center of star ground (so transient currents do not flow through sensitive circuitry or the Neuron chip area)
    - Network connector
    - Power supply connector
    - I/O connectors
  - Make connection to a metal chassis at the center of the star ground
  - If the chassis is not metal, consider where external metal can be placed near your product

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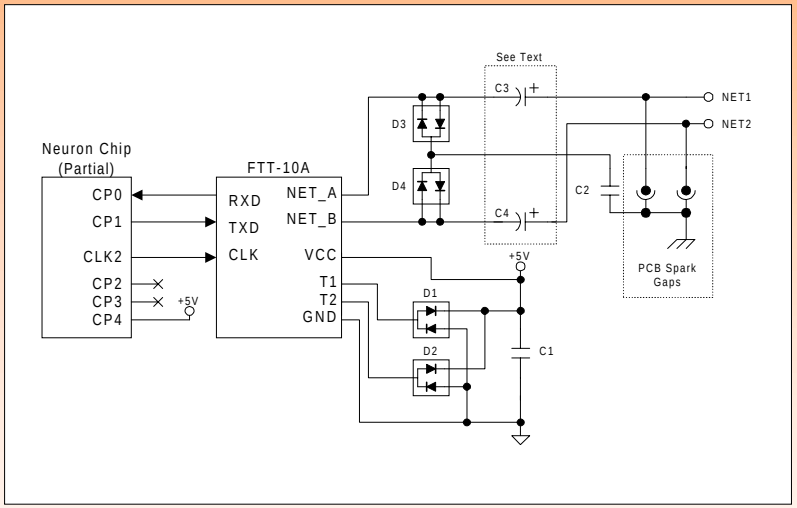
General PCB Layout Considerations



- Chassis and logic grounds can be separate or connected
  - Primary ESD energy is diverted through the spark gaps and C2, so a direct return path to chassis is very important
  - Secondary ESD energy is clamped by D1-D2 and C1, so a direct return to chassis from the transceiver ground is important
  - If logic ground and chassis are separate, connect them with a capacitor at star center (~ 0.01uF)

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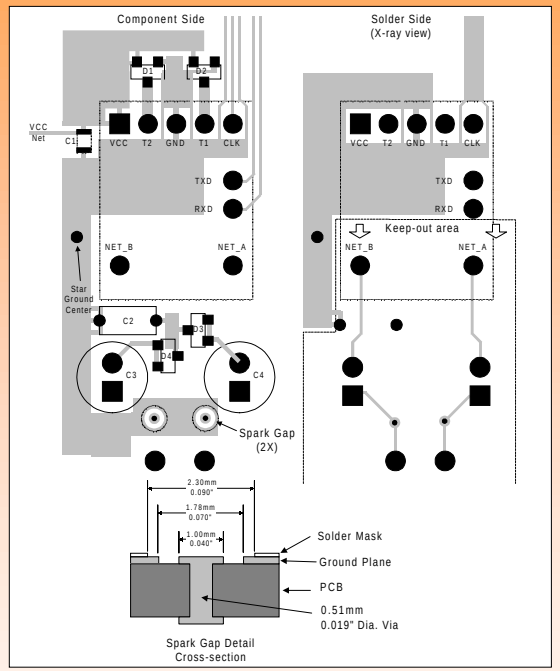
General PCB Layout Considerations



- Transceiver grounding for improved EMC:
  - Lowering the impedance between the transceiver's ground pin and external chassis ground will lower the radiated EMI from the network cable
  - Take advantage of the "open" side of the FTT-10A transceiver (no pins) to route a wide ground pad to the chassis connection point at star ground center
- ESD Keepout Area:
  - Network traces are "ESD Hot," so keep all other traces away

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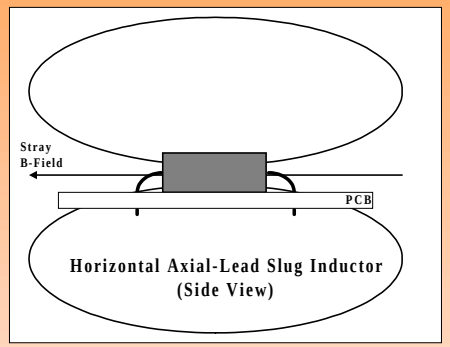
General PCB Layout Considerations

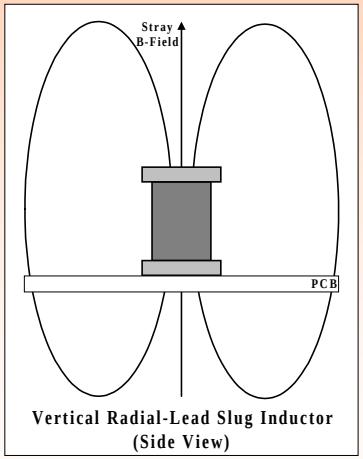
- The order of trace layout for a 2-layer PCB should be:
  - Place a full ground plane on the solder side of the PCB
  - Route the fast digital traces on the component side of the PCB
  - Route the rest of the traces, preferably on the component side
  - Pour ground pads in any open areas, and connect them to the main ground plane with vias
- Keep the leakage capacitance low from digital traces to chassis metal (or external metal outside the product)
  - This reduces the RF noise on your logic ground
- Consider using “VHC” logic in memory interface circuits
  - VHC has AC speed, and slower edges for better EMC

Avoiding Magnetic Field Interference

- All transformer-based transceivers are vulnerable to stray magnetic field noise
- The FTT-10A transceiver is least sensitive to vertical fields, and most sensitive to horizontal fields
- (The old FTT-10 transceiver was the opposite: it was most sensitive to vertical fields)
- To avoid interference with FTT-10A communication:
  - Quiet the sources of magnetic field noise
  - Keep any remaining stray fields vertical at the PCB surface
- Common-mode voltage noise on logic ground can sometimes "masquerade" as magnetic field interference

Sources of Magnetic Field Noise: DC-DC Converter Magnetic Components





- Slug Style Inductors
  - Horizontal axial-lead slug inductors generate horizontal stray fields at the PCB surface
  - Vertical radial-lead slug inductors generate vertical stray fields at the PCB surface
    - Radial-lead slug inductors with built-in magnetic shielding are available (for example: Taiyo-Yuden LHFP type, or TDK FS type)

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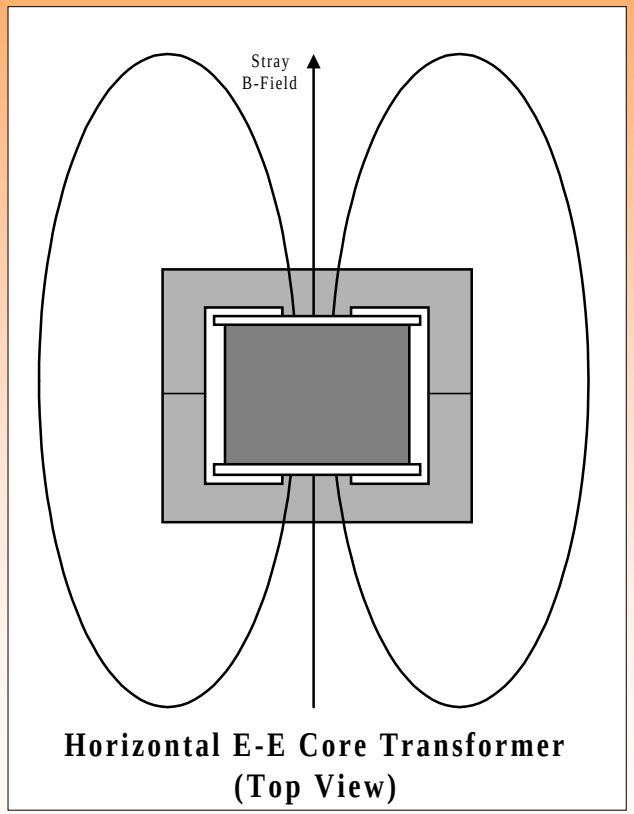
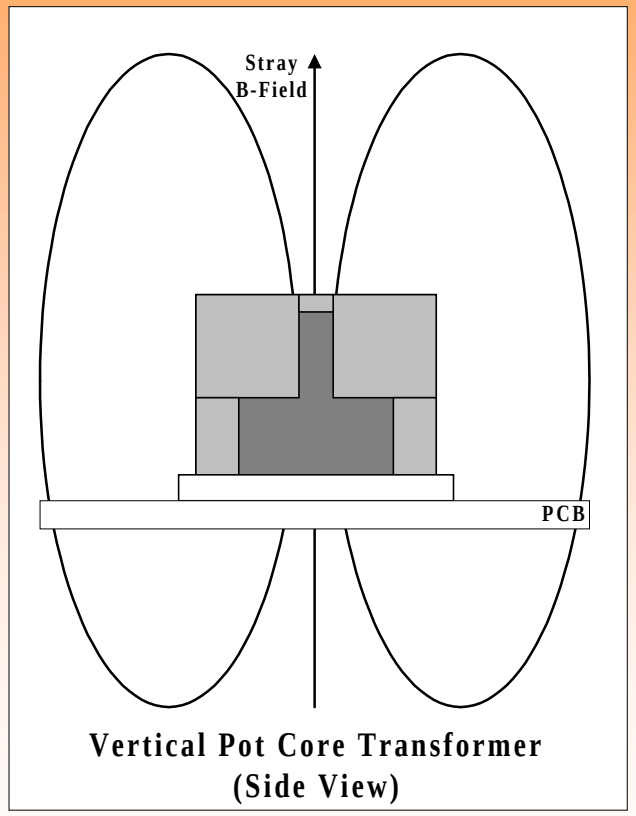
Sources of Magnetic Field Noise: DC-DC Converter Magnetic Components



Horizontal E-E Core Transformer
(Top View)

- Horizontal E-E core transformers generate horizontal stray magnetic fields at the PCB surface
  - The field lines run parallel to the plane of the PC board, which is the FTT-10A transceiver's most sensitive plane

Sources of Magnetic Field Noise: DC-DC Converter Magnetic Components



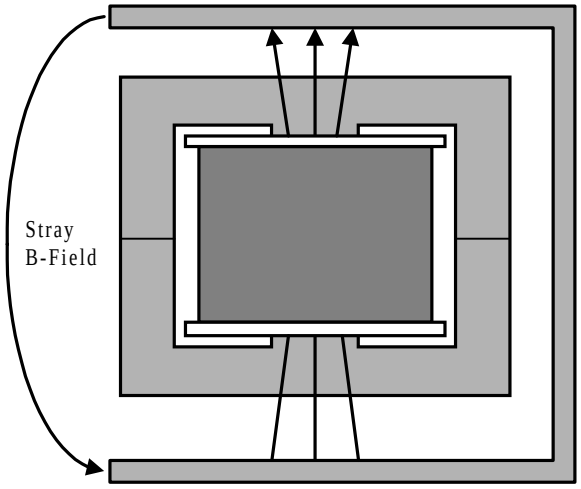
Vertical Pot Core Transformer
(Side View)

- Vertical pot core transformers generate vertical stray magnetic fields
  - The field lines run perpendicular to the plane of the PC board at the PC board's surface, which is the FTT-10A transceiver's least sensitive axis

Avoiding Magnetic Field Interference

- In general, keep the source of stray magnetic field noise away from the transceiver, quiet it down as much as possible, and keep any remaining stray fields vertical as they pass through the PCB
- To quiet a non-isolated “buck” or “boost” DC-DC, use a shielded vertical radial-lead slug (i.e: Taiyo-Yuden LHFP type, or TDK FS type)
- To quiet an isolated transformer-based DC-DC:
  - Best: Use a bifilar, full circumference-wound toroidal transformer
  - Good: Use a vertical pot-core transformer
  - Otherwise: Use a shield fence (made from 1mm thick steel), or an external shorted turn (made from copper tape) with an E-E core transformer
- For harsh magnetic field environments, use a 5-sided steel shield on top of the FTT-10A transceiver

Reducing E-E Core Transformer Stray Fields



Horizontal E-E Core Transformer With 3-Sided Steel Fence Shield (Top View)

- Use a 3-Sided or 4-Sided Steel Shield Fence
  - The shield fence is the same height as the transformer above the PCB
  - Orient the open side of the fence so that it points away from the transceiver
  - The 1mm thick, cold-rolled steel material diverts the stray magnetic field to keep it confined near the E-E core transformer

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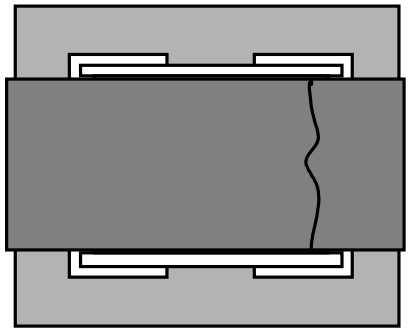
Reducing E-E Core Transformer Stray Fields



Horizontal E-E Core Transformer
With External Shorted Turn
(Top View)

- Use an "External Shorted Turn" around the transformer
  - A wide piece of copper tape provides a low-impedance conductive path to serve as a shorted turn around the stray magnetic field.
  - Use copper tape ≥ 0.4 mm thick, and solder the overlapped ends to form a conductive band
  - Power supply designers: keep in mind that this technique may increase the losses seen by the DC-DC drive circuit, since the transformer's leakage inductance is now shorted out by a low (real) resistance

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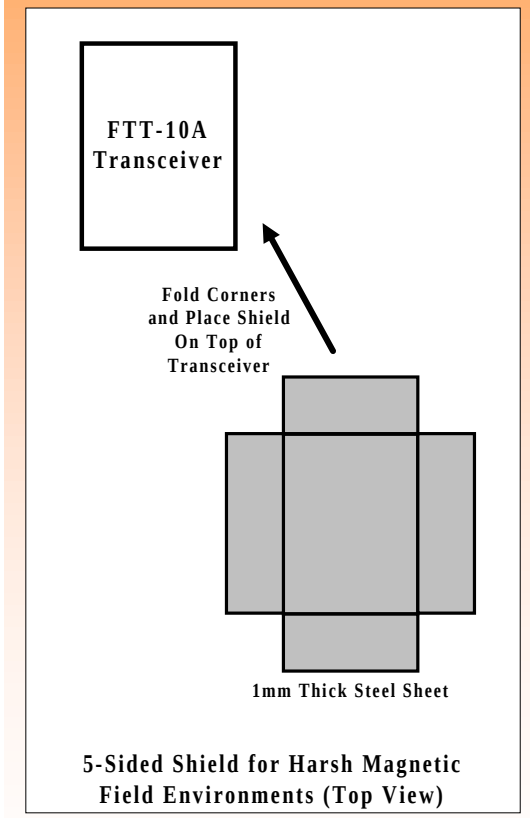
Shielding the FTT-10A Transceiver

- For harsh magnetic field environments, a 5-sided steel shield can be placed on top of the transceiver:
  - Use 1mm thick, cold rolled steel to divert the magnetic field around the transceiver's internal volume as much as possible
  - This shield technique works best if the source of the stray field is above the transceiver, and the stray magnetic field lines are vertical when they pierce the plane of the PCB at the transceiver (so that the 5-sided shield diverts the field around the transceiver volume)



5-Sided Shield for Harsh Magnetic Field Environments (Top View)

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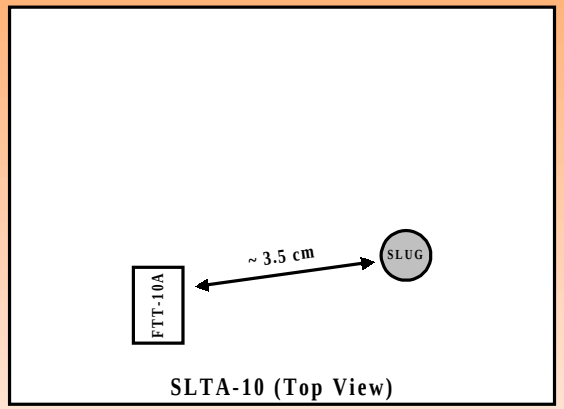
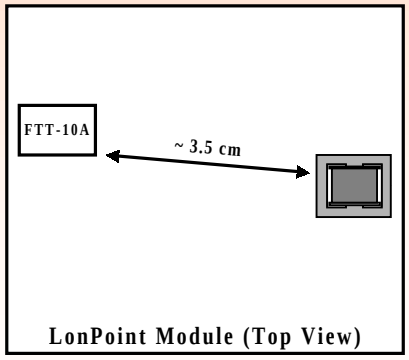
Examples of Products With DC-DC Converters and FTT-10A Transceivers



SLTA-10 (Top View)



LonPoint Module (Top View)

- Two examples of Echelon Products that use DC-DC converter circuits which do not interfere with the FTT-10A transceiver's operation:
  - The SLTA-10 uses a non-isolated "buck" DC-DC converter with an unshielded vertical slug inductor
  - The LonPoint modules use an isolated DC-DC converter with an unshielded E-E core transformer

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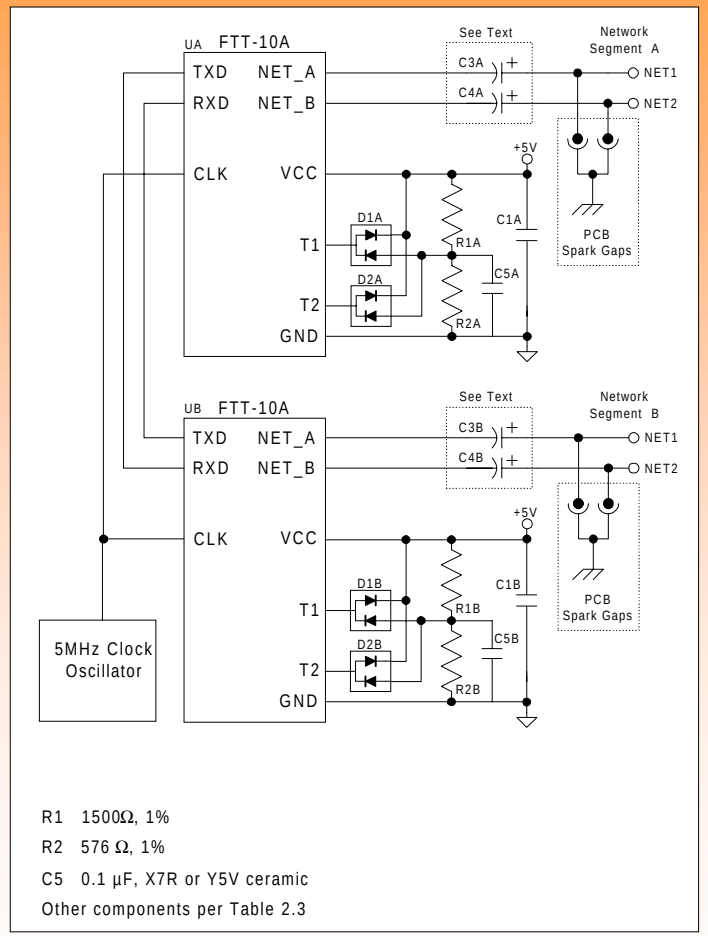
Testing For Magnetic Field Interference

- A node may have enough local magnetic field interference to cause communication problems in a full-size network, but not enough to cause obvious problems in a small network
- A differential probe can be used to check for interference at the FTT-10A receiver's input pins (T1 and T2)
  - Typical differential probes are the HP1141 and Tektronix P6046.
  - Place both tips of the differential probe on T1, and check that no differential voltage is measured. This verifies that the common-mode rejection of the probe is sufficient for this measurement.
  - Place the differential probe across T1-T2. When there is no incoming network signal, there should be < 10mVpp of noise. If there is > 10mVpp of noise, then the DC-DC or some other source is interfering with the full range of performance of the FTT-10A transceiver.

FTT-10A Physical Layer Repeaters



- 0C to +85C version
  - Note that R1, R2, C5 are needed for correct operation
  - The ESD snubber diodes and capacitor (see slide #5) are not needed on physical layer repeaters
  - Keep a 2.5cm clear space between transceiver bodies to avoid magnetic field crosstalk between the transceivers

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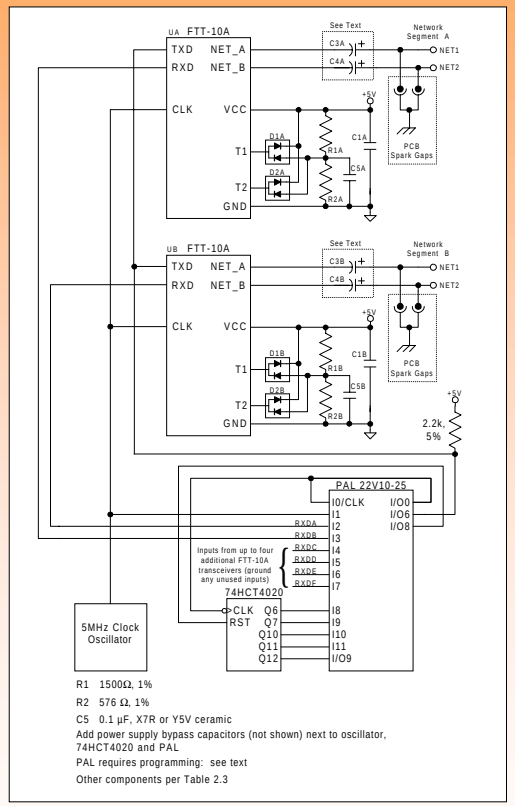
FTT-10A Physical Layer Repeaters

- -40C to +85C version uses a PAL
  - Published in Version 4 of the *FTT-10A Free Topology Transceiver User's Guide*
  - Note that R1, R2, C5 are needed for correct operation
  - Keep a 2.5cm clear space between transceiver bodies to avoid magnetic field crosstalk between the transceivers
  - JEDEC files for the DIP and PLCC 22V10 PALs are available at www.echelon.com



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Using Category 5 Wire With FTT-10A Transceivers

Table 4.2 Doubly-Terminated Bus Topology Specifications

	Maximum bus length	*Units*
Belden 85102	2700	meters
Belden 8471	2700	
Level IV, 22AWG	1400	
JY (St) Y 2x2x0.8	900	
TIA Category 5	900	

A doubly-terminated bus may have stubs of up to 3 meters from the bus to each node.

Table 4.3 Free Topology Specifications

	Maximum node-to-node distance	*Maximum total wire length*	*Units*
Belden 85102	500	500	meters
Belden 8471	400	500	
Level IV, 22AWG	400	500	
JY (St) Y 2x2x0.8	320	500	
TIA Category 5	250	450	

- Version 4 of the *FTT-10A Free Topology Transceiver User's Guide* includes specifications for Category 5 wire
  - "10/100Base-T" cable
  - 24AWG wire

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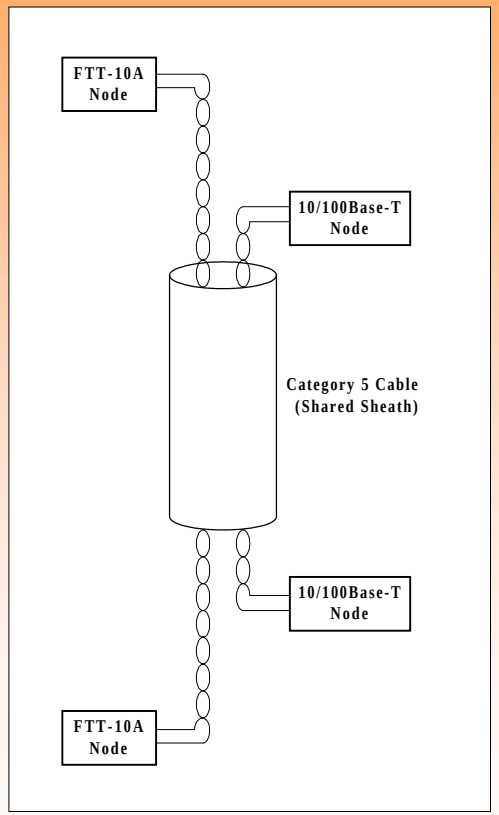
General FT-10 Network Considerations



- Category 5 Crosstalk Study
  - Category 5 cable can contain four or more twisted pairs in the same sheath
  - Echelon has checked for crosstalk interference between FT-10 channel communications and a 10Base-T (or 100Base-TX) channel on an adjacent pair in the same cable sheath
    - There was no interference from the FT-10 channel into the 10/100Base-T channel
    - There was no interference from the 10/100Base-T channel into the FT-10 channel

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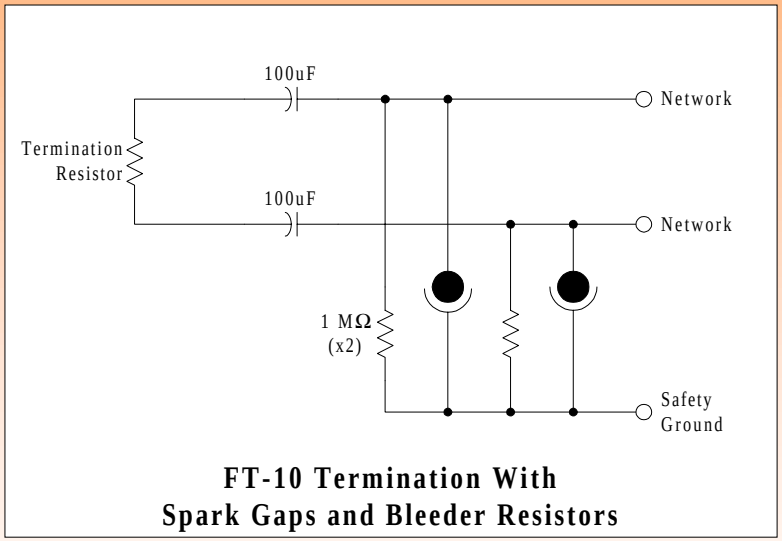
General FT-10 Network Considerations



FT-10 Termination With Spark Gaps and Bleeder Resistors

- Adding spark gaps to a termination
  - If an ESD bleed-off path is desired for the network wiring, then spark gaps and bleed resistors can be used at the termination(s)
  - The diagram at the left shows the termination used with LonPoint modules
  - If the cable is shielded, then a 470kΩ or 1 MΩ resistor can be used to bleed the shield to safety ground

IEC 1000-4-6 Conducted RF Susceptibility

- IEC 1000-4-6 is the upcoming test standard for Conducted RF Susceptibility, and it will increasingly become a test that is performed on products that use the FTT-10A transceiver
- Several of Echelon's products have passed IEC 1000-4-6 (they each use a common-mode choke in the network connection):
  - The LonPoint Modules passed Level 3 (10V/m)
    - They use the muRata PLM250S30T1 SMT common-mode choke
  - The SLTA-10 passed Level 2 (3V/m)
    - It uses the muRata PLT1R53C common-mode choke
  - The PCLTA-10 passed Level 2 (3V/m)
    - It uses the muRata PLT1R53C common-mode choke
- Echelon is conducting more tests on FTT-10A nodes to determine layout guidelines for passing IEC 1000-4-6, including whether some nodes can pass without the use of beads or common-mode chokes in their network connection

Some Troubleshooting Tips

- A presentation from the 1996 LonUsers Convention in France is available: *Troubleshooting LonWorks® Devices and Twisted Pair Networks*
  - It is available from www.echelon.com (look for Troubl2.pdf), and from Echelon Technical Support