<table>
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<th>Title</th>
<th>Contact Information</th>
</tr>
</thead>
<tbody>
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</tr>
</tbody>
</table>
A. EMI Topics

1. Challenges of EMI
2. Typical EMI sources and how to find them
3. Low, broadband and high frequency EMI problems
4. Typical & numerous EMI fixes
5. How to prevent EMI problems in original designs
6. New EMI challenges for today’s products & future products
B. Review of EMI Topics Related to Magnetics/Ferrites

1. Interesting & unique properties
2. EMI coupling model- How ferrites reduce noise -
   a) How ferrites reduce noise at the source
   b) How ferrites reduce noise at the victim
3. Information you need to design with ferrites
4. Effective physical placement of ferrites
5. Little secrets other folks may not tell you
6. Common-mode vs. differential-mode current and voltage
7. Design tradeoffs & comparisons
8. Appendix
C. Applications

1. DC power bus filtering
2. AC input power filtering
3. Fundamental sources of EMI in switch-mode power supplies
4. Using ferrites to reduce EMI at input and output of SMPS
5. Sneaky problems
6. Question and answer + Bring your “favorite” problem

D. Product Presentation

1. Cable cores
2. Common-mode chokes
3. Differential-mode beads/arrays
4. Inductors
1. Challenges of EMI

- Radio frequency emissions from electronic products are regulated over the frequency range of (at least) 10 KHz to 40 GHz

- Conducted and radiated emissions limits require noise currents on antenna structures (external cables, external chassis surfaces) and AC, some DC, some signal ports to be $<10^{-5}$ amps (0.00001A) (10 uA)

  - The majority of electronic devices utilize functional currents of at least 1 mA

  - Systems must achieve a minimum of 40 dB isolation between the *intended* signals on PCBs, connectors, cables, and the *unintended* signals on antenna structures or power cabling
2. Typical EMI Sources - What Do They Look Like?

Predictable, periodic, non-random signals are made up of many large (size) frequencies called “harmonics”. These are strong EMI sources.

Unpredictable, non-periodic, random signals are made up of smaller, wider, “fuzzier” harmonics. These are weak EMI sources.
2. Typical EMI Sources - What Do They Look Like?

Square wave with finite rise time (trapezoidal)

Fundamental Frequency = \( \frac{1}{T_o} \)
Pulse width = \( \tau \)
Risetime = \( \tau_r \)

“Slow edges yield weaker high frequency harmonics”
“A 50 MHz clock is worse than a 75 MHz clock if it has a faster risetime”
“Low-pass filtering in frequency slows the edge rate in time”
2. Typical EMI Sources - How ferrites can help solve the noise problem

- The series impedance of ferrites can be used to form a portion of a low pass filter at the signal output of an electronic device. In the time domain, the rise and fall times of the base waveform are increased. In the frequency domain, higher frequency signal harmonics are reduced, and so we have a weaker noise source. Low impedance (Z<100 ohm) SMT ferrite beads can be used at a signal output to damp or terminate the oscillations that may otherwise occur on the edges of fast digital signals.

- Care must be taken not to excessively slow digital signal edge rates. In microprocessor applications, setup and hold times may be violated. In power electronics, power dissipation can be adversely affected.
2. Typical EMI Sources - How to Find Them

An interesting noise problem that we see frequently involves noise coupling from high speed silicon ICs with and without heat sinks.

Noise is coupled from the IC to nearby antenna structures such as portions of conductive chassis or wires attached to the PCB.
2. Typical EMI Sources - How to Find Them

In some cases this noise model can be verified and an economical solution found by taking “before and after” EMI emissions measurements using the following actions:

a) temporarily removing the heatsink, or
b) temporarily bonding the heatsink to chassis or PCB signal return, or

c) placing a Steward ferrite plate directly on top of the IC or trace.

Ferrite has a relative permittivity greater than air and so can simultaneously provide magnetic and dielectric loss.
3. Low, BB, And High Frequency EMI Problems

Our customers face EMI design challenges that can span seven decades of frequency! Consider an optical networking system:

- Ref clock @ 9 kHz
- SMPS @ 400 kHz
- Logic PCB Memory from 133 to 500+ MHz
- High power laser at 2.4 or 10.2 GHz
4. Typical EMI “Fixes”

EMI CAN BE REDUCED IN A NUMBER OF WAYS;

- Move components on the PCB
- Add or improve return (“ground”) planes
- Reduce the length of high speed “noise source” PCB traces
- Improve signal integrity in noise source circuits by adjusting characteristic impedance of signal path along PCB traces or wiring, or adding termination components
- Add filters consisting of inductors, capacitors, resistors, or combinations of these parts.
- Change active circuit components, lower sink/source current, slower rise/fall times
- Use special shielding techniques

Adding lossless energy storage components such as inductors and capacitors can only reflect or redirect EMI, with the possible result of squeezing the EMI sausage from one frequency to another
4. Typical EMI “Fixes”

EMI CAN BE REDUCED BY

- Adding ferrite products

When used most effectively, FERRITES will ABSORB the EMI energy, dissipating it as tiny amounts of heat (microwatts)

BE SURE TO USE THE RIGHT FERRITE PRODUCT
5. Adding a Ferrite Bead to the Decoupling Network, Using Power “Islands”

- Provide a low impedance power bus on/in the PCB for high speed digital logic. Use ferrites to provide filtered power to attenuate conductive coupling from digital noise sources to the larger PCB power planes and attached wires.
- When might it help reduce PCB generated EMI?
- When might it help increase PCB generated EMI?
- When might intended circuit function be impaired?
6. New EMI challenges for today’s products & future products

Noise Source ➔ Path ➔ Victim or Antenna

1) Clock, address, and data timing is now often controlled to 100 pS in relatively low-cost systems. Low impedance SMT ferrites can be used to replace series resistor terminations ($Z_{FB} < Z_0$)

2) The high level of silicon device integration “buries” the noise problem where it cannot be easily remedied - at the source, and brings the problem directly to the PCB. Examples: Magnetics and LEDs imbedded into network connectors, BB noise introduced by open frame SMPS

3) EMC troubleshooting of hardware at the design stage may steal precious days in the product development cycle, where product lifetimes are measured in months. Engineering labor is expensive, cheaper alternatives are tempting to those who pay our salaries
1. Interesting & Unique Properties of Ferrites

Exactly what are ferrites?

1) Ferrite is a homogeneous ceramic material composed of various oxides. The main constituent is iron oxide, which is blended with small quantities of other materials (like nickel) to achieve specific L, R, and Z versus frequency design goals.

2) Ni Zn material is lower perm material, Mn Zn is higher perm material

3) Volume resistivity is also controlled by composition
1. **Four Useful and Interesting Properties of Ferrites**

1) A frequency dependant “lossy impedance” that can provide significant attenuation to unintended noise and low insertion loss for intended signaling. Insertion loss at DC and AC power frequencies can be neglected in many circumstances.

2) “High” magnetic permeability which concentrates a magnetic field within the core. **Benefit**: Big L, R, Z for small package.

3) High electrical resistivity which limits eddy currents in the core. **Benefit**: Ferrites can be used as efficient transformer cores at high frequencies (1MHz - 1+GHz) using an appropriate material composition.

4) Manufactured using “sticky powder” compaction like medicine pills. **Benefit**: Unique shapes and sizes are easy to manufacture to address specific applications. Toroids, beads, cores, plates, etc.
Ferrite Bead Equivalent Circuit

1) Frequency dependent loss & inductance
2) “Low” Z at “low” F
3) Peak Z at “mid” F
4) “Low” Z at “high” F
Typical Impedance Curve

HZ0805E601R-00

Z, R, X vs FREQUENCY

Impedance, Resistance, Inductive Reactance

Steward EMI Suppression Technical Presentation
2. How Ferrites Reduce Noise & EMI Coupling Model

Emissions and Immunity/Susceptibility:

Noise Source → Path → Victim or Antenna

a) reduce high frequency content of the noise source by providing a series impedance that reduces noise current amplitude

b) increase the impedance of the path to provide attenuation between noise source and victim

c) increase the input impedance of the antenna or circuit impedance of the victim with the goal of reducing noise current amplitude

d) reduce the “Q” of the source, path, victim, or antenna by inserting loss to damp undesired frequency-selective behavior
3. Information You Need When Designing with Ferrites.....

What is the application?
- Power filtering, signal line filtering, SMT, cable suppression

What is the maximum amplitude of the circuit voltage?
- To be consistent with other insulators in the application circuit
- To avoid excessive DC or low frequency AC voltage drop

What is the maximum amplitude of the circuit current?
- Higher ampacity implies larger size
- DC and low frequency bias effects must be considered (more in a minute)
3. When Designing with Ferrites.....

What is the bandwidth or frequency of your intended signal?
  • Don’t break the signal you really want
  • EMC engineers want/need to keep design engineers happy

What is the lowest and highest noise frequency?
  • Choose the optimum material type for frequencies of interest

Do you know what impedance or inductance value you need?
  • Unlikely, except when;
    • IC vendor application note calls out a specific p/n or value
    • “Signal” and “noise” frequency bands are closely spaced
3. When Designing with Ferrites.....

• In DC or AC power filtering, “bigger” $|Z|$ is usually “better”

• In PCB design applications, need $R_{dc}$ low enough to ensure tolerable signal or Vcc voltage drop
  • Is $(i_{\text{max}} \cdot R_{dc}) < 0.05 V_{CC}$?

• Generally want $|Z|$ as big as possible to attenuate “noise”, but not so large as to affect intended signal.
  • Is $Z_{dm}$ of ferrite < 0.1 $Z_0$ over BW of intended signal?

• The higher the “initial permeability” $\mu_i$, the lower the application frequency
4. Effective Physical Placement of Ferrites

- How close is “good enough”? How far away is “too far”?
- The correct, exact placement of a ferrite is often discussed during PCB and cable assembly design.
- If we consider small enough segments (\(\ell/20\)) of PCB trace or wire, for a given frequency we can say that current and voltage are essentially constant over the segment. This segment length defines the distance that “doesn’t matter” for placing/nudging parts in a design.

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>Electrically short trace or wire length</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15 m</td>
</tr>
<tr>
<td>10</td>
<td>1.5 m</td>
</tr>
<tr>
<td>100</td>
<td>15 cm</td>
</tr>
<tr>
<td>1000</td>
<td>1.5 cm</td>
</tr>
</tbody>
</table>
5. Little Secrets Other Folks May Not Tell You

Lossy ferrite core materials intended for use above 30 MHz are generally “high Q” (2\(\frac{\omega L}{R}\) \(\gg\) R) below 30 MHz.

Underdamped (it rings!) for \(L > R^2 \frac{C}{4}\), for \(R=10\,\Omega\), \(C=20\,\text{pF}\), \(L > 0.5\,\text{nH}\)!!

Intended signals of low impedance, low loss digital circuits operating from 100 kHz to 10 MHz may oscillate if a high Q ferrite bead is introduced.
Typical Impedance Curve

HZ0805E601R-00

Z, R, X vs FREQUENCY
The effects of bias

The impedance vs. frequency characteristic of small ferrite devices exhibits a change when DC or low frequency AC bias (current) is changed.
**Size Matters**

Size-Bias Comparison

120Ω Chips, 200ma DC

- LI1812
- LI1206
- LI0805
- LI0603
- LI0402

**Impedance (ohms)**

**Frequency (MHz)**
Ferrite Chip Impedance Performance Affected by Size and Bias Current

| Steward Part Number | $|Z|$ (ohms) @ 100 MHz | $|Z|$ (ohms) @ 500 MHz | $|Z|$ (ohms) @ 1 GHz |
|---------------------|---------------------|---------------------|---------------------|
| HZ1206C601R         | 600* (550)          | 220* (220)          | 105* (120)          |
| HZ0805E601R         | 600* (380)          | 304* (250)          | 151* (120)          |
| HZ0603601R          | 600* (300)          | 330* (420)          | 171* (200)          |
| HZ0402A601R         | 600* (175)          | 644* (600)          | 399* (500)          |

* Impedance at zero DC bias current - normally the default value shown on data sheets
( ) Impedance at 100 ma DC bias current

In general, above 1 GHz, a smaller part provides optimum impedance
In general, below 1 GHz, a smaller part shows a larger “apparent” drop in $|Z|$ under bias
Differential-Mode Currents & Voltages

- The *intended* circuit currents that appear in an electrical circuit by design, and that can be calculated in advance using lumped element or transmission line circuit models.

\[ \oint \mathbf{H} \cdot d\mathbf{l} = I_{\text{enclosed}} = 0 \]

(Ampere's Law)

- If we put a *current probe* around BOTH conductors, we expect the current probe to find equal and opposite magnetic fluxes, and therefore zero NET current in the conductor pair.
Common-Mode Currents

- The unintended component of signal current. Common-mode currents can be viewed as a set of identically valued currents flowing in the same direction on a group of conductors.

- A current probe around THIS cable will show a net, unintended, common-mode “noise” current present.
A DC Filter With Two Ferrite Beads

- Does this filter affect *common-mode* signals?
- Does this filter affect *differential-mode* signals?
A DC Filter With a Single Ferrite Core

- Does this filter affect *common-mode* signals?
- Does this filter affect *differential-mode* signals?
CM Filter Applications

• **High current** (I >= 3 A) generally require common-mode structure to reduce effects of load-dependent bias and |Z| vs. frequency shift (High current chip beads can still be effective if de-rating performance is considered and for higher frequency noise.)

• **High frequency** (where $F_{\text{noise}}$ and $F_{\text{signal}}$ overlap or are spectrally similar generally require common-mode structure to maximize noise attenuation while minimizing insertion loss to intended signal.
- Differential-mode impedance is the impedance inserted by the filter that is seen by the intended signal circuit.
- If the source and load impedance of the differential-mode (intended) circuit are known, the attenuation of the intended signal can be easily calculated

\[ 20 \log_{10} \left( \frac{\|Z\|_{\text{source}} + \|Z\|_{\text{load}} + \|Z\|_{\text{filter}}}{\|Z\|_{\text{source}} + \|Z\|_{\text{load}}} \right) \]
Testing Common-Mode Chokes

Differential-Mode

The impedance that the intended circuit sees when in operation. (black arrows)

Common-Mode

The impedance that impedes common-mode (noise) current (red arrow) along the circuit path

“Open Mode”

The impedance of a single leg with all others open circuited
Two wire differential circuit is shown with the defined current paths (black arrows) and the associated magnetic flux paths around the wires. The red arrows depict the common-mode current path and the associated flux paths.

The same two wires shown above have been fitted with two EMI cores in a differential-mode configuration, with one core per line. In this configuration, each core must handle the entire differential mode noise of each line as well as the common-mode noise passing down the wires (red arrows). Thus the designer must be concerned with possible magnetic saturation of the core.

The same two wires have now been fitted with an EMI core in a common-mode configuration, a single core with both lines through the core. The black fields in the core are now equal and opposite, which yields a net load seen by the core of approximately zero. The common-mode noise path (red arrows) is additive, while the base signal effect is removed due to the balance of the field generated by the differential-mode circuit. So, saturation is not as much of an issue, and a much smaller core / choke can be used.

The magnetic descriptions are the same for a Cable Core or a Surface Mount Ferrite Part.
Filtering CM Noise on Attached DC Cables

"WRONG"

"RIGHT"
7. Design Tradeoffs and Comparisons

• For the control of EMI, desire good filter performance at low cost over the WIDE range 10 kHz-40 GHz!!

• To get high performance from traditional L-C-L filtering, need many L’s and C’s, but this can lead to ugly high frequency resonances

• Adding lossless energy storage components such as inductors and capacitors can only reflect or redirect EMI, with the possible result of squeezing the EMI sausage from one frequency to another

• EMC engineers love “loss”. What we need is an all purpose EMI resistor that does not affect DC, AC power, or low frequency intended signaling. This is a ferrite EMI suppressor!
7. Design Tradeoffs and Comparisons

Advantages of specific devices

- Multi-line arrays can be used to “consolidate” single line ferrite beads to reduce placement costs on cost-sensitive designs.

- Common-mode chokes can be used to “consolidate” small-signal and large current power line filtering in a single part to reduce placement costs and to reduce a design’s unique part count.

- Bigger parts with greater cross sectional area in general exhibit less impedance shift and “derating” when used under bias.
Design Rules For Placement of Ferrite SMD’s

- Cracked SMDs may result when located in an easily warped location on the PC board.
- SMD breakage probability by stress at a breakaway is illustrated below. The probability of part breakage is highest with example A, followed by B, C and D.

Placement and orientation of SMD’s

- Proper placement
- Improper placement
- Improper under certain conditions

- Ferrites often are designed close to the edges of PC boards. Failure is most often seen where “flex” movement occurs.
- Proper location of the part, especially larger parts, is critical to insure problem-free singulation.
- Singulation stresses often appear minor to the average observer. However, small unrecorded shock waves are sufficient to break a ceramic component.
- Insufficient spacing between components may cause solder bridging. The minimum spacing between components is the greater of 0.5 mm or 1/2 the height of the solder face of the component.
- Ferrite requires a good pre-heat cycle.
- Large ferrite parts will have cold solder joints without a good pre-heat cycle.
- Why?
  - Ferrite is a thermal sponge, and a large ferrite block will pull out a lot of heat from the conductors. This can cause a poor solder joint if a good pre-heat is not provided.
1. DC Power Bus Filtering

Why do EMC engineers care?

1) The DC bus is a conducted path between noise sources (digital ICs) and attached antennas (wires) (emissions)

2) The DC bus is a conducted path between attached antennas (wires) and susceptible ICs. (immunity)

4) The DC bus forms a portion of a conducted path between noise sources (digital ICs, SMPS) and the external EMI network (LISN) during conducted emissions and immunity testing

5) AC-DC and DC-DC power supplies are not reliable noise filters!

Noise Source ➔ Path ➔ Victim or Antenna
1. DC Power Bus Filtering

- We want \(|Z_B| = 0\) from DC to light to achieve zero volts of noise on Vcc

- We want \(|Z_{FB}| >> |Z_B|\)
- Give me big \(\Phi@F>0\) Hz
- Give me 0 \(\Phi@F=0\)

Steward EMI Suppression Technical Presentation
2. AC Power Input Filtering

Why do EMC engineers care?

1) AC-DC and DC-DC power supplies are not reliable noise filters!

2) Power supplies are sold primarily on the basis of a transfer function $H(j\omega)$ for one direction only!
2. AC Power Input Filtering

• Most radiated emissions problems associated with a system AC power cable are due to either:

  1) Near-field coupling from nearby electronics to internal cable pigtail
  2) Near-field coupling within the power supply, that is converted to a noise current on the AC power cable.

• A properly installed ferrite core or ferrite-based filter assembly provides noise reduction for both cases
2. AC Power Input Filtering
3. Fundamental Sources in SMPS

1) ESR of bulk capacitors on HV bus for DM emissions below 1 MHz
2) Large loop area between bulk capacitors and switch
3) Excessive interwinding capacitance across T1
4) Lack of common-mode return path and common-mode filtering at output
5) Inadequate damping or “snubbing”, especially at switch and diode
4. Fundamental Sources in SMPS + Ferrite Solutions

1) Common-mode ferrites at the DC output help attenuate DC power bus noise that is headed for the AC input.
2) Common-mode ferrites at the AC input help the primary AC line filter at frequencies above 10 MHz or so.
3) Note: In most converters, the primary switching loop is a bad place for a ferrite. Typical switching frequencies in low cost commercial converters are still <few MHz, where most EMI suppression ferrites are low loss.
5. A Couple of Fun Sneaky Problems

- Inductive coupling occurs from a) main converter transformer and/or b) primary loop to
c) AC input filter magnetic components, and/or
d) AC input traces and wiring

- Significant concern in compact power supply designs
Material Comparison

EMI MATERIALS FOR CABLE & WIRING HARNESS CORES
- LF  Low Frequency
- 27  Lower Wide Band
- 28  Wide Band High Performance
- HF  High Frequency

Circuit design, part shape & size affect impedance. Additional wire turns multiply impedance.

Due to continuous material improvements, please consult Steward's website for latest information.
Select the appropriate ferrite material for the frequency range to be attenuated (refer to Steward cable core material impedance vs. frequency chart).

Shape of the ferrite core can shift peak impedance frequency. (Example: Flat ribbon / flex cable cores provide higher frequency impedance than cylindrical cores)

Select a ferrite core that fits over the cable’s outside dimensions. Core should slide easily over the cable during installation.

In every installation possible, install a cable core over wires in a common mode configuration (out and back lines inside the same cable core). A differential cable pair inside the same core will make the core a common mode choke that is not susceptible to saturation from very high currents.
Design & Selection “Rules of Thumb”
Steward EMI Ferrite Cores for Cables & Wiring Harnesses

- Generally, **mass of the ferrite core affects impedance**.
- **Impedance varies** almost proportionally **with** the change in **length of the cable core**. (A core 10 mm long will have about half the impedance of a 20 mm long core with the same outside & inside diameter)
- **Part length is somewhat variable** if a longer or shorter part is desired. (Reference Steward’s diagram dimension “C”)
- **Additional turns through a core will provide multiple amounts of peak impedance**. [Example: two wire turns provide 4 times the impedance of one turn (pass through) the ferrite core]. Also, with each added turn, the peak impedance shifts to a slightly lower frequency.
Design & Selection “Rules of Thumb”
Steward EMI Ferrite Cores for Cables & Wiring Harnesses

- One piece cylindrical or flat ribbon ferrite core shapes give the best performance but, **split cores are available** for applications where cores cannot slide over cable ends. Some split cores are available with snap-on plastic cases or metal clips.

- **Ferrite core part designs should not interrupt the magnetic path** around the ferrite core wall. (Example: a notch should not cut into and reduce the ferrite core wall thickness)

- Ferrite core impedance measurement equipment and test methods are not standardized in the industry. **Side by side impedance testing of ferrite cores is the best way to compare performance of different cores.**
Impedance with 1 Turn and 2 Turns

Steward Ferrite Core 27B1020-100

Z vs. Frequency

Impedance (Ohms)

Frequency (MHz)
Surface Mount Components with Multiple Turns
Impedance with Multiple Turns

CM6032V301R-00

Z vs. Frequency

Frequency (MHz)

Impedance

1T
2T
3T
4T

Steward EMI Suppression Technical Presentation
Low Normal-Mode Impedance

CM2722R201R-00, CM3822R201R-00, CM5022R201R-00

Z vs. Frequency
Open, Common and Normal Mode

Impedance (Ω)

Frequency (MHz)
Gigabit Ethernet EMI Filtration

Fig1.

CM5022RXXXR-00

1000BASE-T Ethernet Tx / Rx

PCB Ethernet Connector

CM5022R201R-00
Power Filtering using Common-Mode Chokes

Common and differential mode noise from 300 – 800kHz SMPS conducted via VCC and GND lines.

High frequency digital noise from CLK’s, ASIC’s etc on PCB’s, coupled onto VCC and GND lines.

Various PCB Cards e.g. Digital, Telecomms, Switching etc

19” Rack / EuroRack etc
Low to High Frequency Common-Mode Performance

CM3440Z171B-00
Z, R X vs Frequency

CM5740Z241B-00 - 2 Turn
Z, R, X vs Frequency
Low to High Frequency Common-Mode Performance

CM5441Z161B-00

CM5441Z990B-00

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Impedance with Multiple Turns

Z vs. Frequency
CM6032V301 4T

Frequency (Mhz)
Impedance (ohms)

0 500 1000 1500 2000 2500
0.10 1.00 10.00 100.00 1000.00 10000.00

Steward EMI Suppression Technical Presentation   Slide 63
Impedance vs. Frequency

Inductance vs. Frequency
CM6032V301R-00

Steward EMI Suppression Technical Presentation
Inductance vs. Current

Inductance vs. Current @ 100Khz
CM5441Z990B-00

- Open Mode (with normal mode bias)

Steward EMI Suppression Technical Presentation

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### Steward Advanced Common-Mode Chokes for Power and Data Line

<table>
<thead>
<tr>
<th>Part Family</th>
<th>Special Features</th>
<th>Size</th>
<th>Z @ 100</th>
<th>Current</th>
<th>Peak Freq</th>
<th># of lines</th>
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<tbody>
<tr>
<td>CM 22 Beads</td>
<td>Hi Current, Small Package, Hi Freq</td>
<td>1922 - 3322</td>
<td>33-120</td>
<td>3/10</td>
<td>1 - 2 Ghz</td>
<td>2</td>
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<tr>
<td>CM 22 Array</td>
<td>USB 2.0 / Firewire, Gigabit Ethernet</td>
<td>2722 - 5022</td>
<td>45 - 200</td>
<td>5</td>
<td>200 - 700 MHz</td>
<td>4/8</td>
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<tr>
<td>CM 32 Array</td>
<td>Hi Current, Hi Freq</td>
<td>3032 - 6032</td>
<td>120 - 300</td>
<td>8</td>
<td>150 - 500 MHz</td>
<td>4/8</td>
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<tr>
<td>CM 40 Array</td>
<td>Hi Current, Low to High Freq</td>
<td>3440 - 5740</td>
<td>170</td>
<td>20</td>
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<tr>
<td>CM 41 Choke</td>
<td>Ultra Hi Current, Low to High Freq</td>
<td>5441</td>
<td>90-160</td>
<td>55</td>
<td>3-500 MHz</td>
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Power Filtering with Differential-Mode Chip Bead

- +Vcc
- CLK/Square Wave Generator
- Processor ASIC etc.
- Comm's IC
- LCD Driver
- LCD

- Ferrite Chip Impeders
- Ferrite 4-Line Chip Array

PCB Edge Connector
Differential-Mode Chip Bead Broadband Performance