Enabling Lower Cost Advanced Automotive Safety Systems Through Hybrid PCB Construction
Outline

- Printed Circuit Board (PCB) requirements for advanced automotive safety systems
- Hybrid PCB construction and benefits
- PCB material processing requirements for hybrid constructions
- Material availability in industry
- Summary
Advanced Automotive Safety Systems
Active Safety Systems

Radar Sensor Portfolio
- 25 GHz Ultra-wide Band Radars
- 24 GHz Narrow-band Radars
- 77 GHz Multi-mode Radars

Supporting
- Blind Spot Detection
- Rear Cross-traffic Alert
- Lane Change Assist
- Forward Collision Warning
- Autonomous Emergency Braking
- Adaptive Cruise Control
Vehicle Radar Classification

- **Long Range Radar (LRR)**
  - Range up to 250 m
  - Vehicle velocity above 30 km/h to 250 km/h
  - Narrow beams to control driving path in front of the car to determine distance of vehicle driving ahead for maintaining minimum safety distance
  - Bandwidth below 1 GHz and typical spatial resolution 0.5 m

- **Short Range Radar (SRR)**
  - Range up to 30 m
  - Speed range from 5 km/h to 150 km/h
  - Wide field of view
  - Bandwidth below 5 GHz and typical spatial resolution 0.1 m
RADAR Resolution Requirements

- **Scenarios Requiring High Resolution (wide bandwidth)**
  - Side Impact
  - Cross Traffic Alert
  - Narrow Pass Assistant
  - Evasion Maneuver
  - Pedestrian Protection
  - Front Collision Warning
  - Proximity Warning and Parking Assistant

- **Scenarios Needing Lower Resolution (narrow bandwidth)**
  - Adaptive Cruise Control – long range
  - Lane Change Assist – 24 GHz
## Frequency Bands for Automotive Radar

<table>
<thead>
<tr>
<th>Frequency Band</th>
<th>Application</th>
<th>Center Frequency</th>
<th>Band Width</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>24 GHz NB</strong></td>
<td>ACC</td>
<td>~24.2 GHz</td>
<td>0.2 GHz</td>
</tr>
<tr>
<td><strong>24 GHz UWB</strong></td>
<td>SRR</td>
<td>24.5 GHz</td>
<td>5 GHz</td>
</tr>
<tr>
<td><strong>26 GHz</strong></td>
<td>SRR</td>
<td>26.5 GHz</td>
<td>4 GHz</td>
</tr>
<tr>
<td><strong>77 GHz</strong></td>
<td>ACC/LRR</td>
<td>76.5 GHz</td>
<td>1 GHz</td>
</tr>
<tr>
<td><strong>79 GHz</strong></td>
<td>MRR/SRR</td>
<td>79.0 GHz</td>
<td>4 GHz</td>
</tr>
</tbody>
</table>

Source: Infineon
Automotive Radar Development

Target is “Accident-free” Driving

Automotive Radar

First Experiments
μ-Prozessors & μW-HL
Greyhound with AWR
‘Distronic’ (ACC)
Distronic Plus, BAS Plus, PAS
3. Gen. ACC
HRR
SRR @ 79 GHz
APG, LCMS, BSD
Accident-Free Driving

<10 35 24 77 24+77 77 79 GHz

Source: IWPC
It is clear that all systems will migrate to the 76 – 81 GHz band in the short to medium term.

Source: IWPC
Active Safety System Development

Systems are migrating to higher frequencies
- Change in frequency allocation
- Improved performance
- Reduced size and improved affordability

Source: Infineon
Active Safety System Trends

- Shift to higher frequencies
  - 76 GHz to 81 GHz
  - Development ongoing at 140 GHz

- Integration of multiple system functions in one chipset
  - Radar front end
  - Microcontroller

- Reduction in system size
  - Smaller size offers more options for integration into vehicle front and rear fascia

- Increasing demand for system cost reductions for a widening target market
Desirable PCB Electrical Properties

- **Low dissipation factor, \( Df = \tan\delta \)**
  - Maximize power delivered to antenna
  - Achieve desired effective isotropic radiated power (EIRP) with lower input power, \( P_{in} \)
  - Better \( s_{11} \) characteristics at resonance
- **Low dielectric constant, \( Dk \)**
  - Allows rapid signal propagation
- **Consistent \( Df, Dk \) over operating bandwidth of SRR and LRR**
  - Provides consistent transmission line impedance
  - Prevents phase distortion of waveform (due to frequency dependence on phase velocity)
- **Consistent \( Df, Dk \) over temperature of operation (-40°C to 85°C) and varying humidity**
  - Eliminates need for compensation for impedance mismatch and attenuation changes over operating range of vehicle
Additional PCB Attributes

- **Material must have consistent physical properties**
  - Uniform electrical properties
  - Consistent physical properties – thickness, Dk, Df
  - Uniformity batch-to-batch and within batch

- **Ease of processing**
  - Minimum amount of special material treatment for PCB fabrication
  - Single cure cycle with parameters consistent with mature products, well established at board shops

- **Low cost as possible**
  - Choose *sufficient* material to satisfy requirements
  - Choose material process-compatible with Hybrid PCB construction
Sources of Loss in PCB

- Dielectric Loss
- Conduction Loss
Dielectric materials have polarized molecules that move when subjected to the electric field of a digital signal. This motion produces heat loss. Loss results in signal attenuation that increases in direct proportion to signal frequency.
PCB Material Conduction Loss

- The copper contributes to overall loss through the metal’s resistive losses.

- At high signal frequencies, the current in PCB copper is concentrated within a small depth near its surface (skin effect).

- Reduction in effective cross-sectional area increases the effective resistance.
Conductor Surface Roughness

- Conductors on PCBs do not have perfectly smooth surfaces
- Rough copper improves peel strength of laminate
- Maximum peak-peak tooth size varies ~ 2-10 microns
- Surface roughness increases bulk copper resistance 10-50%
- Electrical impact of conductor roughness increases with increasing frequency

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Skin Depth (Copper)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 Hz</td>
<td>9.3 mm</td>
</tr>
<tr>
<td>10 MHz</td>
<td>21 µm</td>
</tr>
<tr>
<td>100 MHz</td>
<td>6.6 µm</td>
</tr>
<tr>
<td>1 GHz</td>
<td>2.1 µm</td>
</tr>
<tr>
<td>10 GHz</td>
<td>0.66 µm</td>
</tr>
</tbody>
</table>
Copper Foil Plating

Foil is fabricated by plating copper on a drum

Foil Treatment

Cathode Plating Drum

Copper Anodes

Copper Electrolyte Solution

Drum Side

Matte Side

DSTFoil®

or RTF (drum side)

Standard Foil
Roughness parameters measured with profilometer

RTF
Rq=2.6 um, RF=1.85

VLP
Rq=0.68 um, RF=1.3
Effects of Surface Roughness

- Increase in capacitance due to singular electric fields on surface spikes

- Increase in signal group delay over perfectly smooth

- “Apparent” increase in Dk to match group delay vs frequency characteristics
Automotive Radar PCB Conclusions

- Dissipation factor, Df is typically specified in the range of 0.002 – 0.005 over frequency of operation

- Low profile copper such as VLP2 is necessary to reduce overall loss and eliminate group delay effects versus frequency

- Materials with these attributes come at a premium cost
Hybrid PCB Construction
Hybrid PCB Construction

- **Multi-layered PCB using dissimilar materials**
  - FR4 plus HSD optimized material
  - FR4 plus RF optimized material

- **Reasons to use hybrid construction include**
  - Reduction in overall system cost
  - Optimization of electrical properties
  - Improvement in reliability* and manufacturability

- **Application areas where hybrids are used**
  - Power amplifiers for cellular base stations
  - Ku band low noise block down converters
  - High-speed data channels – PCI Gen 3,4 for example
  - Advanced automotive safety systems
Reliability Concerns

- Laminates having good electrical properties for RF/Microwave applications can have high CTE relative to other materials in construction.

- This high CTE will cause problems when PCB experiences thermal cycling:
  - High CTE material expands at different rate than copper causing delamination
  - Plated through holes undergo stress causing cracking

- Materials in hybrid construction should have well-matched CTEs, reasonably close to that of copper.
Cost Savings

- Material for best radar performance comes at a cost premium, so use it only on critical layers.
- Hybrid material mix must be compatible and not increase fabrication cost and complexity or reduce yield.
- Fortunately, high performance materials are available that make hybrid builds straightforward using well established processes.
Process for Maximum Cost Savings

- To realize the greatest cost savings, use materials that process most closely to FR-4
- Additional or more complex steps required in processing can consume cost savings associated with hybrids
  - Plasma etch for microvia plating
  - Use of multiple plasma surface treatment cycles
  - Plasma desmear
  - Time-constrained electroless and soldermask processes
  - Plasma to promote bond of photo resist for secondary imaging
Transmission Line Guidelines

- For asymmetric stripline it is best to have the thinnest layer being low loss.
- Asymmetric stripline can be more susceptible to cross-talk if Dks differ. This is mitigated by slight increase in gap, g.
- Microstrip takes full advantage of low-loss materials.
This hybrid structure utilizes high performance material where necessary and standard process-compatible materials to reduce cost.

This construction processes like standard FR-4.
Conclusions

- Hybrid constructions offer significant cost savings when the correct materials are used.
- The savings realized is more than just material costs as processing costs can be different depending on the high performance PCB material utilized.
- For best results consult the PCB manufacturer for guidance.