GENERAL

atc resistors and terminations engineering guidelines

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Introduction

In modern high speed digital systems, maintaining signal integrity is paramount. One critical component that often determines the success of a design is the proper use of **ATC resistors and terminations engineering guidelines**. These guidelines help engineers select, implement, and validate resistive elements that match impedance, reduce reflections, and protect sensitive circuitry. Whether you're working on a data center interconnect, a high frequency RF link, or an automotive CAN bus, understanding how to apply these engineering principles can make the difference between a reliable product and one that fails under load.

What Are ATC Resistors?

ATC stands for **Analog Technology Components**, a leading manufacturer of precision resistors and terminations designed for high performance applications. ATC resistors are engineered to exhibit stable resistance over a wide temperature range, low noise, and minimal parasitic inductance or capacitance. These attributes are essential when the resistor's role extends beyond simple voltage division to actively shaping signal edges and managing power dissipation.

Key Characteristics

- Temperature Coefficient (TCR) – Typically
- Power Rating – Ranging from 1 /mW to 1 /W, allowing selection based on current density and heat sinking requirements.
- Package Options – Surface mount (SMD) and through hole formats, with leadless designs for high density boards.
- Noise Performance – Low Johnson noise, critical for analog front ends and sensor interfaces.

Types of ATC Resistors

ATC offers a diverse lineup tailored to specific signal integrity scenarios:

1. Series Termination Resistors – Used to match line impedance and dampen reflections on transmission lines.
2. Shunt Termination Resistors – Ground side termination to provide a low impedance return path.
3. Bias Resistors – Provide reference voltage while maintaining high input impedance.
4. Pull Up/Pull Down Resistors – Ensure defined logic levels on open drain or tri state buses.

Termination Basics

Terminations are resistive elements placed at the end of a transmission line to match its characteristic impedance. Proper termination prevents signal reflections that can lead to data errors, ringing, or even device damage. The most common termination schemes are:

- Single Ended Termination – A resistor between the signal line and ground.
- Differential Termination – Two resistors forming a balanced pair, often implemented as a resistor network.
- Resistive Termination Networks – Combining series and shunt resistors for complex impedance matching.

ATC Resistors and Terminations Engineering Guidelines

Below is a structured set of guidelines that engineers can follow to ensure optimal performance when incorporating ATC resistors and terminations into their designs.

1. Define the Electrical Requirements

Before selecting a resistor, gather the following data:

- Signal frequency and rise/fall times.
- Transmission line length and characteristic impedance.
- Maximum allowable voltage and current.
- Temperature envelope and thermal gradients.

2. Calculate the Required Termination Value

For a single ended line, the termination resistance (R_t) equals the line's characteristic impedance (Z_0). In a differential system, each side typically uses a resistor equal to half the differential impedance (Z_d/2). Example: For a 100 /:' Æ–æP, use a 100 /:' 6W ies termination; for a 100 /:' F–f`erential pair, use 50 /:' W" 6–FP.

3. Select the Correct ATC Part

Match the calculated resistance with an ATC part that satisfies:

- Power rating "e required dissipation ($P = I^2R$).
- Temperature coefficient
- Lead time and availability.
- Package suitability for the PCB layout.

4. Layout Considerations

Signal integrity starts with the PCB layout:

- Keep trace lengths short and symmetrical.
- Maintain a constant trace width and spacing to preserve Z_0.
- Place the termination resistor as close as possible to the end of the line.
- Use ground planes to provide a low impedance return path.
- Avoid stubs and unnecessary vias that introduce discontinuities.

5. Thermal Management

Resistors can dissipate significant power in high speed applications. To manage heat:

- Use larger package sizes (e.g., 0805 or 1206) for higher power ratings.
- Include thermal vias or copper pours adjacent to the resistor.
- Consider adding a heat sink or thermal pad if the power dissipation is close to the resistor's limit.

6. Verify with Simulation

Before fabrication, run a signal integrity simulation (e.g., using HyperLynx, ADS, or CST) to confirm that:

- Reflections are below the acceptable threshold (typically
- Rise/fall times meet the system's timing budget.
- Voltage swings remain within device tolerances.

7. Implement Robust Testing

After assembly, perform the following tests:

1. Time Domain Reflectometry (TDR) – Verify impedance matching and locate discontinuities.
2. Eye Diagram Analysis – Ensure clean eye openings at the target data rate.
3. Thermal Imaging – Check for hotspots around the resistor.
4. Power Supply Integrity (PSI) – Confirm that the resistor does not introduce noise into the supply rails.

8. Document and Review

Maintain detailed design documents:

- Parts list with ATC part numbers.
- Calculated power dissipation and thermal analysis.
- Simulation results and test data.
- Revision history and change logs.

Design Considerations for High Speed Interfaces

When working with protocols such as PCIe, USB 4, or 100G Ethernet, the termination strategy becomes more nuanced.

PCIe and USB 4

These interfaces use differential pairs with 100 :• characteristic impedance. ATC's 50 :• series termination resistors are often paired with a 50 :• shunt to ground to achieve the required differential impedance. Engineers must also account for the skew between pairs and ensure that the termination network does not introduce additional capacitance.

100G Ethernet

100G links use multiple lanes, each requiring precise termination. ATC's low noise shunt resistors are ideal for the 50 /:' FW mination at the receiver end. Additionally, designers must incorporate **cable equalization** techniques and use **equalization circuits** that complement the termination network.

Common Pitfalls and How to Avoid Them

- Under rating the Power – Selecting a resistor with a power rating too low for the current leads to overheating and failure.
- Ignoring Temperature Effects – Even a low TCR resistor can drift if the temperature rise exceeds the specified range.
- Poor PCB Routing – Long, asymmetric traces introduce impedance mismatches.
- Neglecting Ground Plane Integrity – A discontinuous ground plane can create high frequency noise.
- Skipping Verification – Relying solely on simulation without real world testing can mask subtle issues.

Case Study: Automotive CAN Bus Termination

An automotive manufacturer needed to upgrade its Controller Area Network (CAN) system to support higher data rates while ensuring compliance with ISO 11898 2. The design team opted for ATC's 120 :• shunt termination resistors placed at both ends of the bus. By following the engineering guidelines, they achieved:

- Reduced reflection coefficient below –10 /dB across the 1 /MHz bandwidth.
- Consistent voltage levels within ±5 /% across temperature extremes.
- Zero failure rate during a 10 million cycle thermal test.

Lessons Learned

- Choosing a resistor with a slightly higher power rating (1 /W instead of 0.5 /W) provided a safety margin for

unforeseen load spikes.

- Adding a small copper pour around the resistor mitigated localized heating.
- Using a dedicated test fixture allowed rapid verification of termination integrity before full system integration.

Conclusion

ATC resistors and terminations play a pivotal role in safeguarding signal integrity across a wide array of high speed digital systems. By meticulously applying engineering guidelines—defining electrical requirements, selecting appropriate components, optimizing layout, managing thermal load, and validating through simulation and testing—engineers can achieve reliable, high performance designs. Whether you're tackling a data center interconnect, a wireless transceiver, or an automotive network, these best practices ensure that your termination strategy not only meets specifications but also stands the test of time.

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