

# Digital Attenuator, 5-Bit, Serial / Parallel Control

## 0.1 - 30 GHz, 31 Attenuation Range



MAAD-011035

Rev. V2

### Features

- 5-Bit, 1 dB LSB, 31 dB Range
- Integrated CMOS Driver
- Parallel or Serial (P/S) Control
- Low DC Power Consumption
- Attenuation Accuracy:  
+/- (0.4 + 7% of attenuation setting) dB
- Lead-Free 4 mm 24-Lead PQFN Package
- RoHS\* Compliant

### Applications

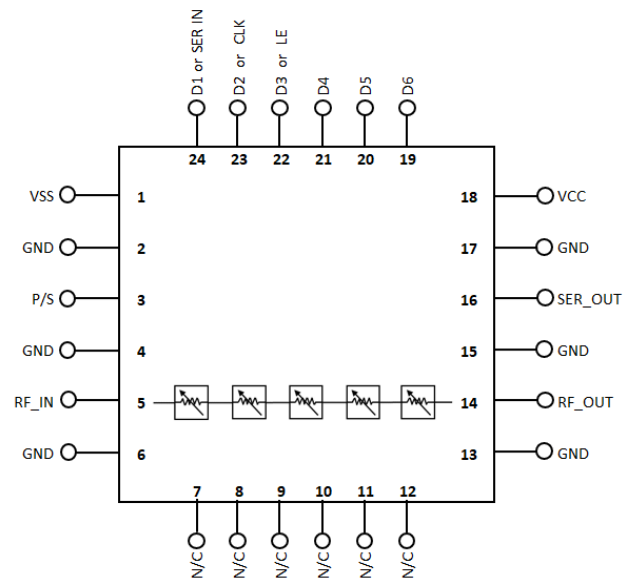
- Test Equipment (instrumentation)
- Communications (commercial and military) :  
Cellular Infrastructure  
Radars  
Radios (MMW)
- General Purpose

### Description

The MAAD-011035 is a wide band 5-bit, 1 dB step GaAs pHEMT MMIC digital attenuator in a lead-free 4 mm 24 lead PQFN surface mount plastic package. This device is ideally suited for use where high accuracy, very low power consumption, and low intermodulation products are required.

This attenuator is controlled with either a SPI compatible serial interface or a 5 bit parallel word.

### Functional Schematic



### Pin Configuration<sup>1,2</sup>

| Pin #               | Function     |
|---------------------|--------------|
| 1                   | VSS          |
| 2, 4, 6, 13, 15, 17 | GND          |
| 3                   | P/S          |
| 7 - 12              | N/C          |
| 5                   | RF IN        |
| 14                  | RF OUT       |
| 16                  | SER OUT      |
| 18                  | VCC          |
| 19                  | D6           |
| 20                  | D5           |
| 21                  | D4           |
| 22                  | D3 or LE     |
| 23                  | D2 or CLK    |
| 24                  | D1 or SER IN |

1. MACOM recommends grounding all N/C (no connection) pins
2. The exposed pad centered on the package bottom must be connected to RF, DC and thermal ground.

### Ordering Information

| Part Number        | Package        |
|--------------------|----------------|
| MAAD-011035-TR0500 | 500 piece reel |
| MAAD-011035-001SMB | Sample Board   |

\* Restrictions on Hazardous Substances, compliant to current RoHS EU directive.

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### Electrical Specifications:

Freq. = 0.1 - 30 GHz,  $T_A = 25^\circ\text{C}$ ,  $Z_0 = 50 \Omega$ ,  $V_{CC} = +5 \text{ V}$ ,  $V_{SS} = -5 \text{ V}$ ,  $P_{IN} = 0 \text{ dBm}$

| Parameter                             | Test Conditions  | Units                                    | Min.                         | Typ.              | Max.                                     |
|---------------------------------------|--|--|------------------------------|-------------------|--|
| Reference Insertion Loss <sup>3</sup> | 0.1 - 18.0 GHz<br>18.0 - 26.5 GHz<br>26.5 - 30.0 GHz                 | dB                                       | —                            | 3.4<br>4.8<br>5.2 | 4.4<br>—<br>6.2                          |
| RMS Attenuation Error <sup>4</sup>    | 0.1 - 30.0 GHz (RMS, mean)   | dB                                       | —                            | 0.4               | —  |
| Attenuation Accuracy                  | Relative to Insertion Loss (0.1 - 30 GHz)                            | ± (0.4 + 7% of attenuation setting) typ. |                              |                   |  |
| Return Loss (IN & OUT) <sup>3</sup>   | All states   | dB                                       | —                            | -12               | —  |
| Input P0.1dB                          | Reference State (beyond 1 GHz)                                       | dBm                                      | —                            | 21                | —  |
| IIP <sub>3</sub>                      | 2-Tone, 10 dBm/tone, 1 MHz Spacing<br>Reference State (beyond 1 GHz) | dBm                                      | —                            | 42                | —  |
| T <sub>RISE</sub> , T <sub>FALL</sub> | 10% to 90% RF, 90% to 10% RF   | ns                                       | —                            | 15                | —  |
| V <sub>CC</sub>                       | —  | V  | +3.0                         | —                 | +5.5                                     |
| I <sub>CC</sub>                       | —  | μA                                       | —                            | 5                 | —  |
| V <sub>SS</sub>                       | —  | V  | -5.5                         | -5.0              | -3.0                                     |
| I <sub>SS</sub>                       | —  | mA                                       | —                            | -0.1              | —  |
| V <sub>H</sub><br>V <sub>L</sub>      | HIGH level control voltage<br>LOW level control voltage              | V  | 0.7 X V <sub>CC</sub><br>0.0 | —                 | V <sub>CC</sub><br>0.3 X V <sub>CC</sub> |
| ESD                                   | HBM  | V  | —                            | Class1A           | —  |

3. Test frequencies = 1 GHz, 18 GHz, and 30 GHz.

4. RMS calculation, mean:

$$RMS \text{ ERROR, mean} = \sqrt{\frac{1}{n} \sum (Er_i - Er_{Ave})^2}$$

### Truth Table<sup>5</sup>

| D6 | D5 | D4 | D3 | D2 | D1 | Attenuation (dB) |
|----|----|----|----|----|----|------------------|
| 0  | 0  | 0  | 0  | 0  | 0  | Reference IL     |
| 0  | 0  | 0  | 0  | 0  | 1  | 1                |
| 0  | 0  | 0  | 0  | 1  | 0  | 2                |
| 0  | 0  | 0  | 1  | 0  | 0  | 4                |
| 0  | 0  | 1  | 0  | 0  | 0  | 8                |
| 0  | 1  | 0  | 0  | 0  | 0  | 16               |
| 0  | 1  | 1  | 1  | 1  | 1  | 31               |

5. "0" = CMOS Low "1" = COMS High (see specifications table)

### Absolute Maximum Ratings<sup>6,7</sup>

| Parameter               | Absolute Maximum                |
|-------------------------|---------------------------------|
| Input Power             | 31 dBm                          |
| V <sub>CC</sub> Voltage | 6 V                             |
| Control Voltage         | -0.5 V ≤ V <sub>C</sub> ≤ 5.5 V |
| Junction Temperature    | +150°C                          |
| Operating Temperature   | -40°C to +85°C                  |
| Storage Temperature     | -65°C to +150°C                 |

6. Exceeding any one or combination of these limits may cause permanent damage to this device.

7. MACOM does not recommend sustained operation near these survivability limits.

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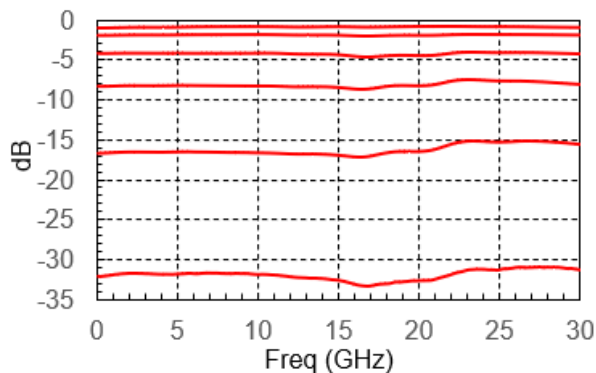


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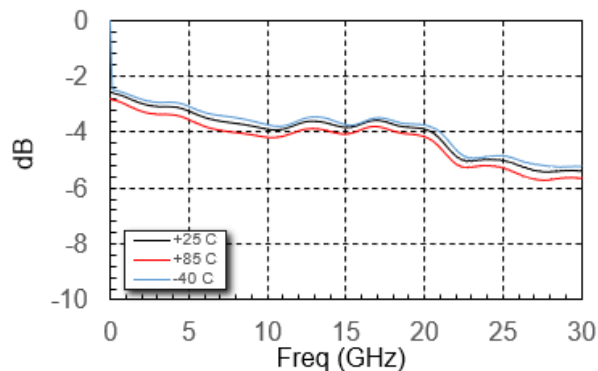
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### Typical RF Performance Plots, @ +25°C

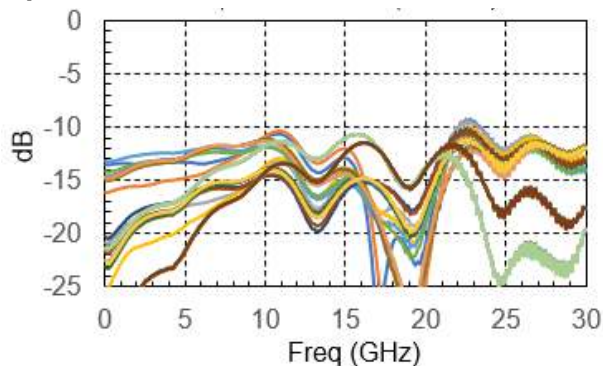
**Relative Attenuation**



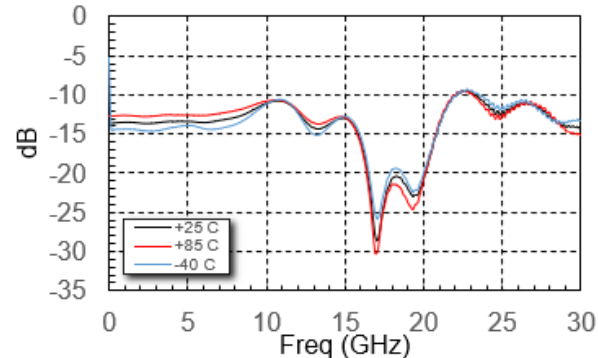
**Insertion Loss vs. Temperature**



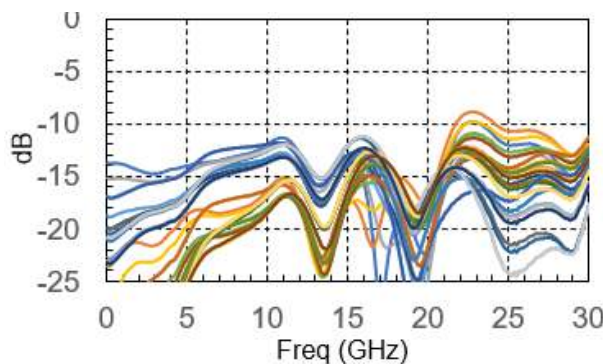
**Input Return Loss (all states)**



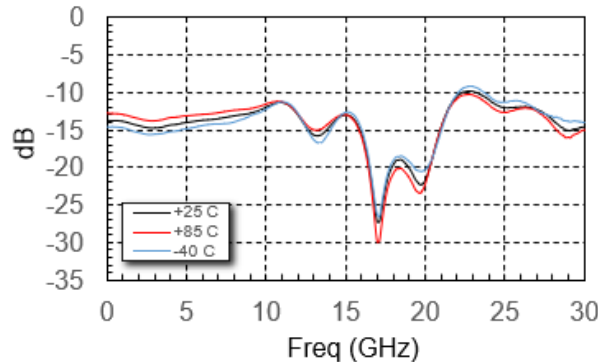
**Input Return Loss vs. Temperature**



**Output Return Loss (all states)**



**Output Return Loss vs. Temperature**



# Digital Attenuator, 5-Bit, Serial / Parallel Control

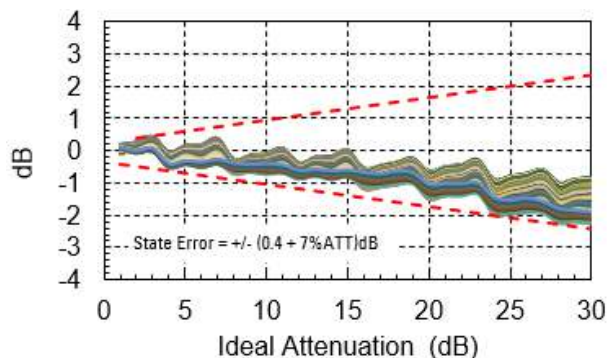
## 0.1 - 30 GHz, 31 Attenuation Range



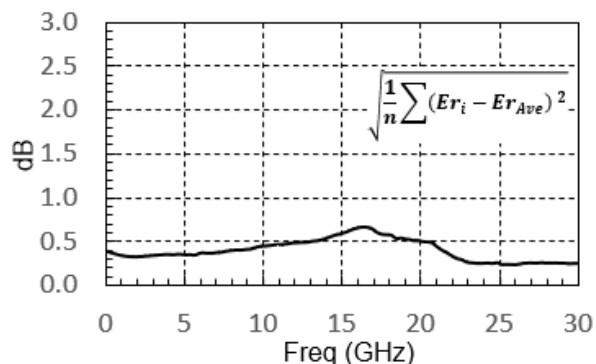
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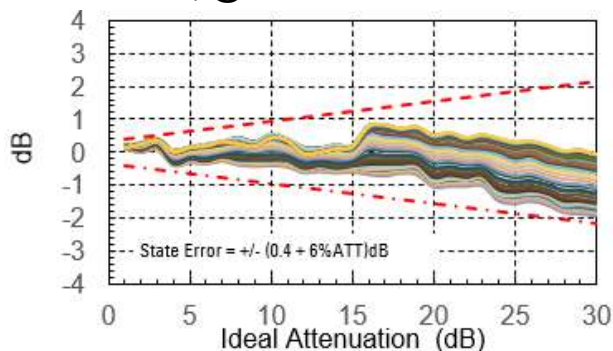
**BIT Error vs. Attenuation State**  
0.1 - 18 GHz, @ +25°C



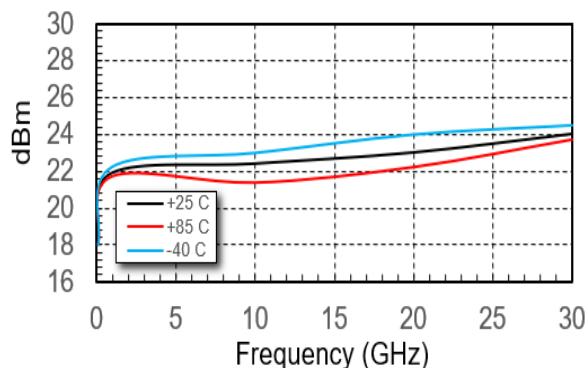
**RMS Error vs. Frequency (mean)**



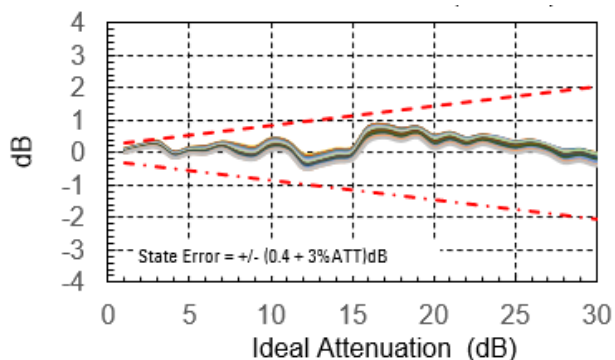
**BIT Error vs. Attenuation State**  
18 - 26.5 GHz, @ +25°C



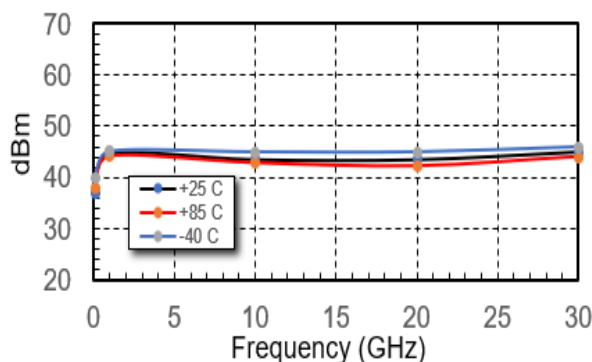
**Input 0.1dB Compression over Temp**



**BIT Error vs. Attenuation State**  
26.5 - 30GHz, @ +25°C



**Input IP3 over Temperature**



## Modes of Operation Serial and Direct Parallel

### Mode Truth Table<sup>8,9,10</sup>

| P/S | LE  | Mode            |
|-----|-----|-----------------|
| 1   | X   | Serial          |
| 0   | N/A | Direct Parallel |

8. There is a dummy bit (D6), that must be sent in the serial mode. This is because this 5 bit digital attenuator uses the same driver as the 6 bit digital attenuator
9. In the parallel mode: D6 should be tied to ground or to  $V_{CC}$ .
10. In the serial mode: D4, D5, and D6 should be tied to ground or to  $V_{CC}$ .

### Direct Parallel Mode

The parallel mode is enabled when P/S is set low. In the direct parallel mode, the digital attenuator is controlled by the parallel control inputs directly. When P/S is set low, pins 22, 23, and 24 have the D3, D2, and D1 function.

### Handling Procedures

Please observe the following precautions to avoid damage:

### Static Sensitivity

These electronic devices are sensitive to electrostatic discharge (ESD) and can be damaged by static electricity. Proper ESD control techniques should be used when handling these HBM Class 1A devices.

### Serial Mode

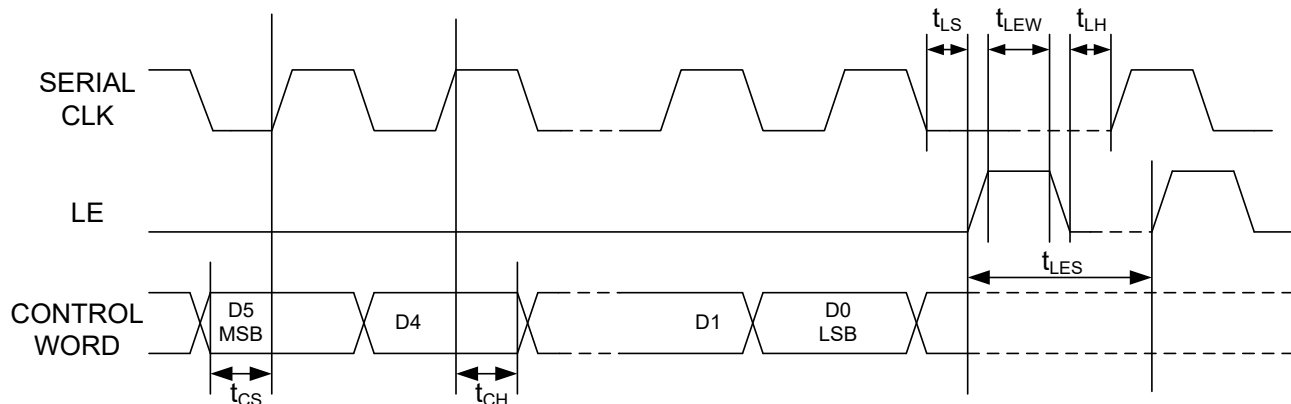
The serial control interface (SER IN, CLK, LE, SER OUT) is compatible with the SPI protocol. SPI mode is activated when P/S is kept high. The 6-bit serial word must be loaded with the MSB first. After shifting in the 6 bit word, a rising edge on LE will set the digital attenuator to the desired state. While LE is high the CLK is masked to protect the data while implementing the change. SEROUT is SERIN delayed by 6 clock cycles.

When P/S is low, the serial control interface is disabled. When P/S is set high, pins 22, 23, and 24 have the LE, CLK, and SER IN function.

In serial mode operation, the outputs will stay constant while LE is kept low.

**Functionality**  
**Modes of Operation: Serial and Direct Parallel**

**Serial Input Interface Timing Diagram**



**Serial Interface Timing Characteristics**

| Symbol    | Parameter                           | Units |
|-----------|-------------------------------------|-------|
| $t_{SCK}$ | Min. Serial Clock Period            | ns    |
| $t_{CS}$  | Min. Control Set-up Time            | ns    |
| $t_{CH}$  | Min. Control Hold Time              | ns    |
| $t_{LS}$  | Min. LE Set-up Time                 | ns    |
| $t_{LEW}$ | Min. LE Pulse Width                 | ns    |
| $t_{LH}$  | Min. Serial Clock Hold Time from LE | ns    |
| $t_{LES}$ | Min. LE Pulse Spacing               | ns    |

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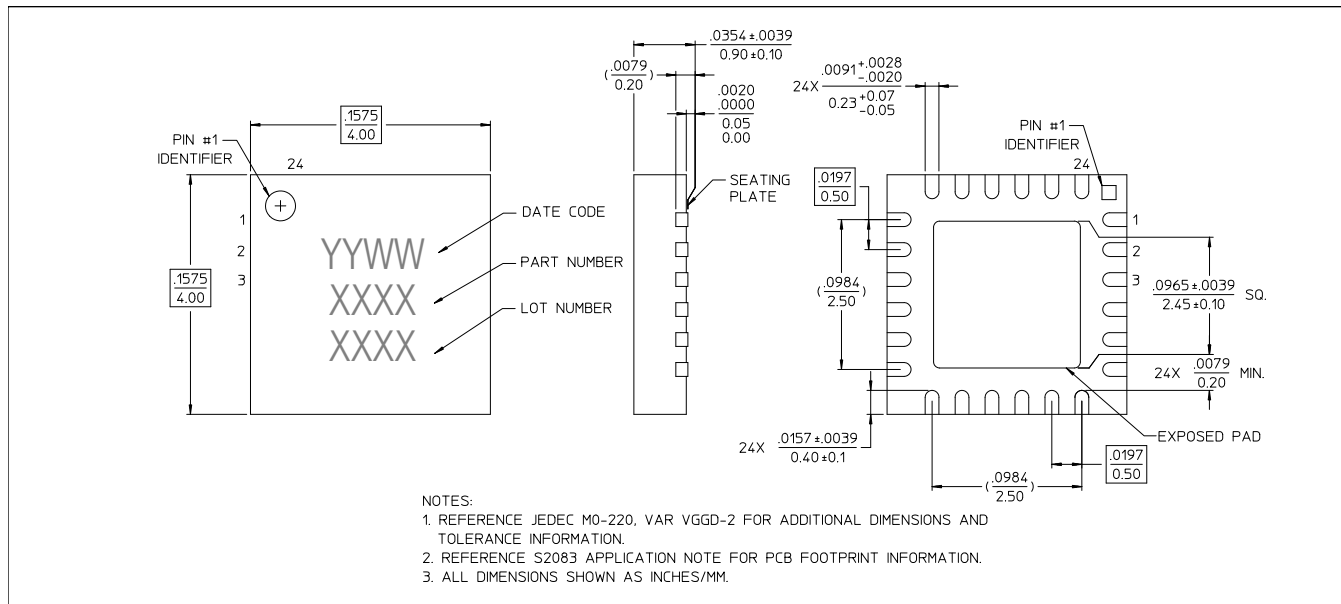
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### Lead Free 4 mm 24-Lead PQFN †



† Reference Application Note S2083 for lead-free solder reflow recommendations.  
 Meets JEDEC moisture sensitivity level 1 requirements.  
 Plating is 100% matte tin over copper.

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