HSMP-3816

High Linearity PIN Diode Pi Attenuator Using a Diode Quad in Low Cost SOT-25 Package

Application Note 5262

Introduction

Avago Technologies' HSMP-3816 consists of four high linearity PIN diodes in one low cost SOT-25 package containing. This device is purposely configured for application as a voltage controlled attenuator based on the PI (π) topology. In addition to the obvious size advantage, bundling four well matched PIN diodes into one part ensures a more perfect symmetry between the attenuator's input and output arms than is realizable using physically distinct parts. This symmetry is advantageous in the interest of linearity.

This paper describes the implementation the HSMP-3816 in a wideband attenuator that spans 0.3 to 3000 MHz. This class of attenuator finds its primary application in cable TV (CATV) networks and set-tops. The secondary application of the PI attenuator is in wireless and cellular communication infrastructure in the VHF and lower microwave region especially where limited space precludes the use of distributed components.

Circuit description

The operating principle of the 4-diode PI attenuator has been explained in AN1048[1]. The attenuator requires a constant voltage, V+ = 1.25V and a variable control voltage, Vc = 0 ~ 5V. The value of V+ represents a compromise between return loss and the required range of control voltage. A lower value of V+ will degrade the return loss at higher attenuation levels but allows the use of a smaller range of control voltage.

The attenuator was implemented on FR4 PCB with a thickness of 0.8 mm. Substituting with better PCB substrates may improve performance at higher frequencies. The frequency dependencies of the various measured parameters are governed by the parasitics associated with the HSMP-3816, PCB, components and connectors.

When PIN diodes are used as the attenuating elements, they offer higher linearity than equivalent GaAs MESFETs[2]. Distortion is minimized with the use of bulk PIN diodes with thick I-layer and low dielectric relaxation frequency (f_{dr}). The Hsmp-381x series has the thickest I-layer thickness in Avago PIN diode product portfolio. At low attenuation, most of the RF energy is simply transferred from the PI attenuator's input to the output port. However, at higher attenuation levels, more of the RF energy is dumped into the attenuator and consequently, the distortion level rises. When the value of Vc approaches zero, almost no current flows through the two series diodes. With these two diodes operating close to zero bias condition, their junction capacitance will vary in synchrony with the RF voltage. Fortunately, some of the distortion generated by the RF modulated capacitance will cancel out because of the two diodes' anti-series connection. The four diodes in one package concept ensure that the distortion cancellation is optimum as the two anti-series diodes are more closely matched than is possible using two randomly picked diodes.

The phase shift through the PI attenuator varies with the attenuation setting. The total phase variation across attenuation is approximately 90 degrees and this remains reasonably constant over three wide-spaced frequencies (100 / 900 / 1800 MHz).

Notes:

1 AN1048 A low cost surface mount Pin diode ð attenuator, Avago Technologies.

2 Higham, E., " Distortion in Voltage-Variable Attenuators" , Microwave Journal, Dec. 1999.

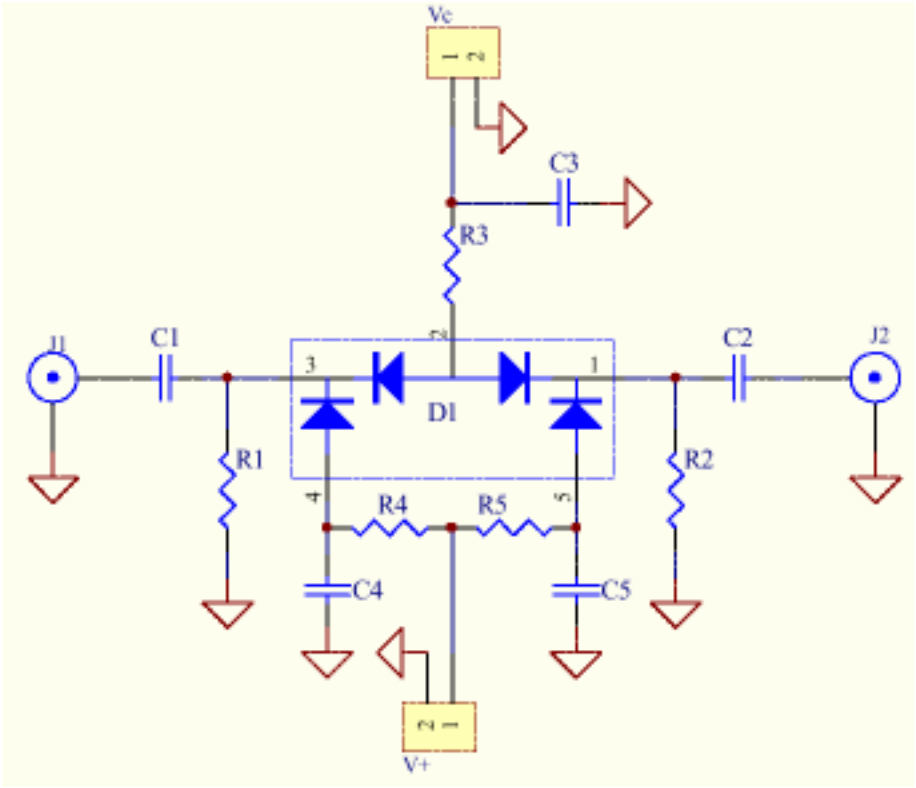


Figure 1. HSMP-3816 Wideband PI attenuator

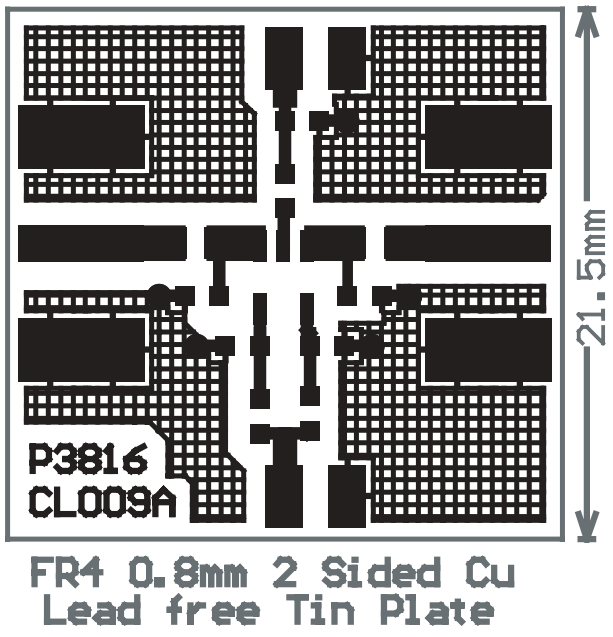


Figure 2. PCB layout

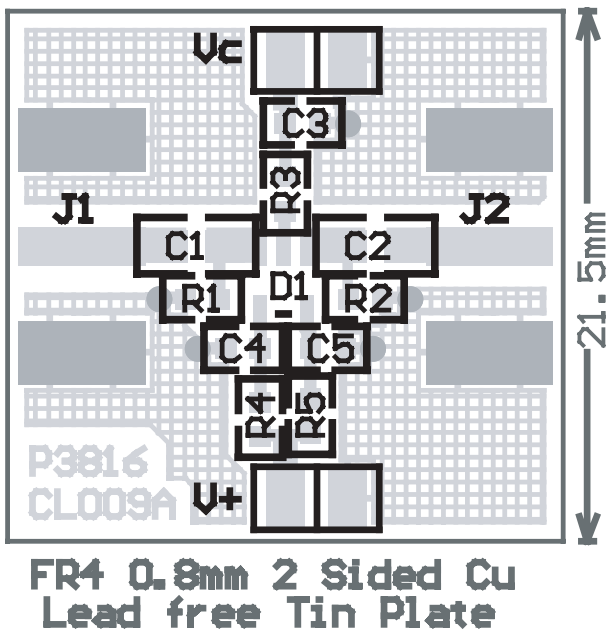


Figure 3. Component placement

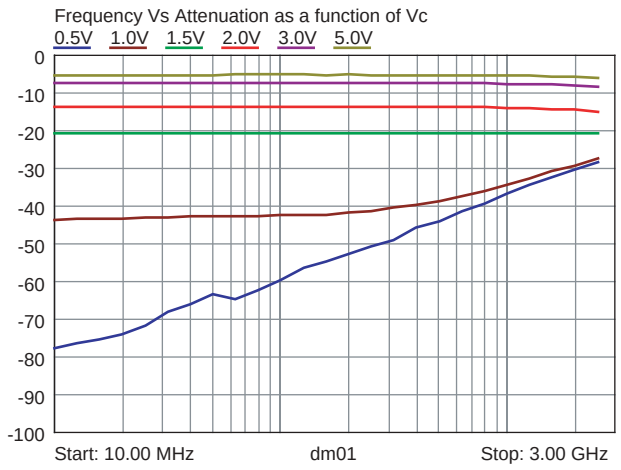


Figure 4. Frequency Vs. Attenuation as a function of Control Voltage

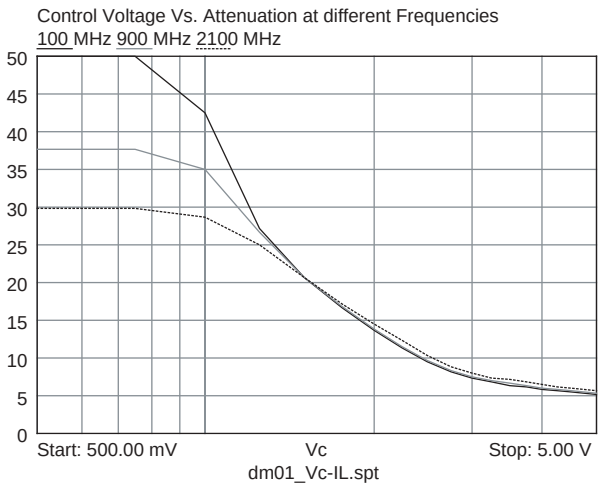


Figure 6. Control Voltage Vs. Attenuation as a function of Frequency

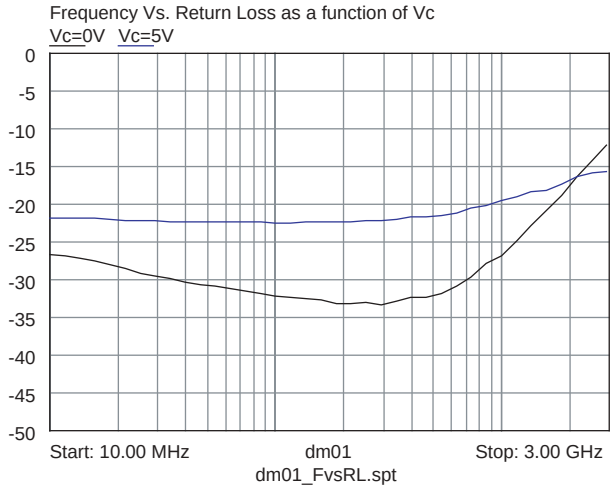


Figure 5. Frequency Vs Return Loss as a function of Control Voltage

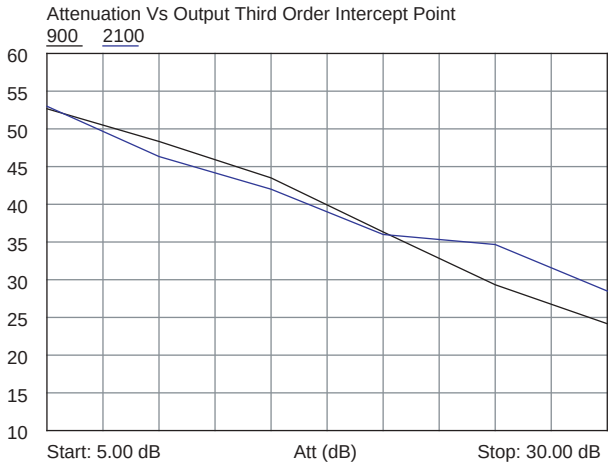


Figure 7. Attenuation Vs Third Order Output Intercept Point at 900 & 2100 MHz

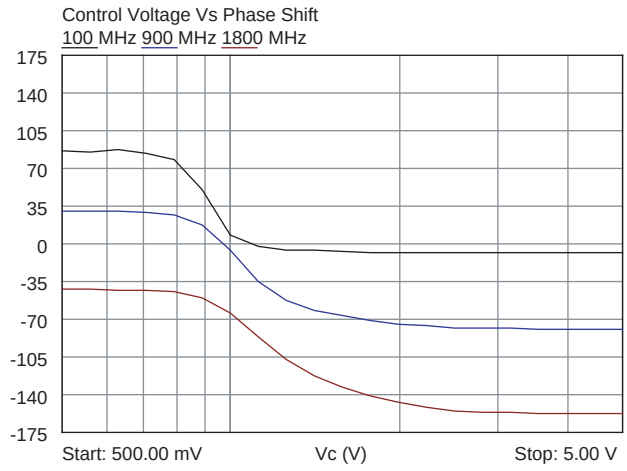


Figure 8. Control voltage Vs. Phase Shift

Part list

Table 1. List of components (standard version)

Position	Value	Size	Manf.
C1- C2	47 nF	0805	Murata
C3 - C5	47 nF	0603	Murata
D1	HSMP-3816		Agilent
J1, J2	Edge mount SMA connector	0.8 mm	
J3, J4	2 pin header		
R1, R2	330 R	0603	
R3	330 R	0603	
R4, R5	150 R	0603	

Appendix 1 – Lower Loss version

The minimum attenuation limit can be lowered by increasing the bias current through the series diodes. While maintaining the maximum control voltage at 5V, the bias current can be increased by reducing the value of R3. A surface mount ferrite bead inductor, L1 is added in series to R3 to provide RF blocking. This ferrite bead inductor has higher impedance over a wider frequency range than a conventional ceramic cored multi-layer chip inductor.

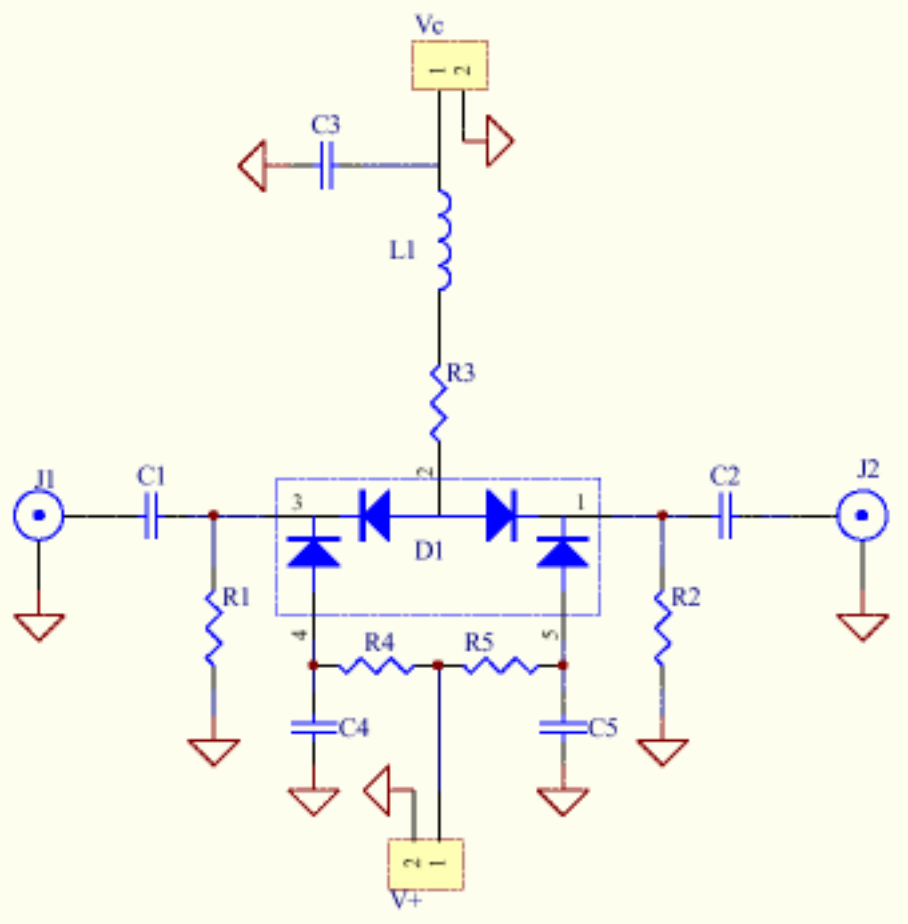


Figure 9. Lower minimum attenuation version of the PI attenuator

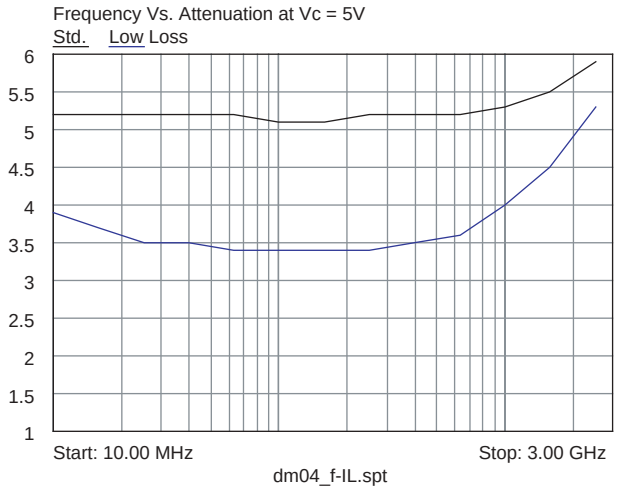


Figure 10. Comparing minimum attenuation (Vc = 5V) of the standard vs. the low minimum attenuation versions

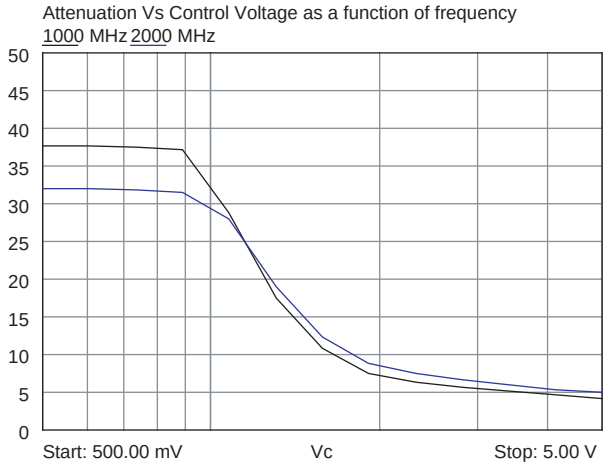


Figure 11. Attenuation Vs Control Voltage (Low Loss Version)

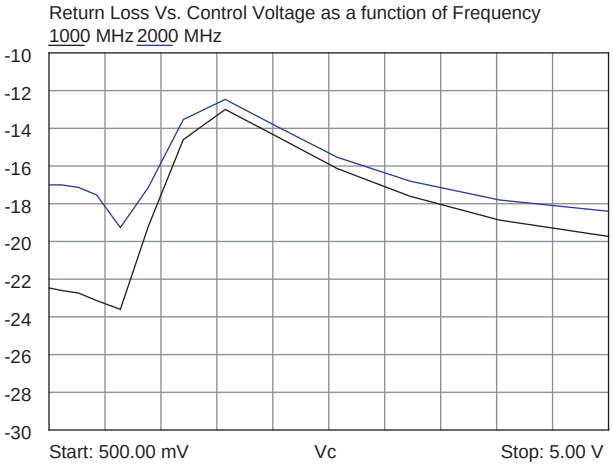


Figure 12. Return Loss Vs. Control Voltage (Low Loss Version)

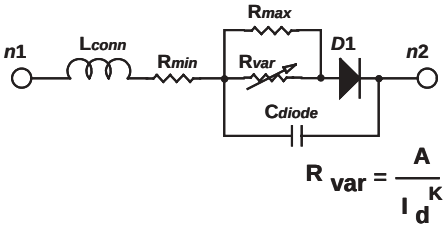
Table 2. Component changes in the low minimum attenuation version

Component	Value	Size	Manf.
L1	BLM18RK102SN1	0603	Murata
R3	82 R	0603	

Appendix 2 –Simulation

Agilent ADS website provides a support example on simulating the 4-diode PI attenuator[3]. The file can be downloaded from the "Examples" section of the Agilent EEsof Knowledge Center
(URL: edasupportweb.soco.agilent.com).

The APLAC Pin diode model can predict the RF resistance for a given value of forward bias. Combining the APLAC model with the SOT-25 equivalent circuit model allows the designer to account for the package parasitics in the simulation.



	HSMP-3816
Rmax, KΩ	12
IS, A	3.04E-09
N	2.064
TT,ns	1500
C, pF	0.289
A	0.0902
K	0.987
Rmin, Ω	2.5
L, nH	2

Figure 13. Hsmp-381x Aplac Model

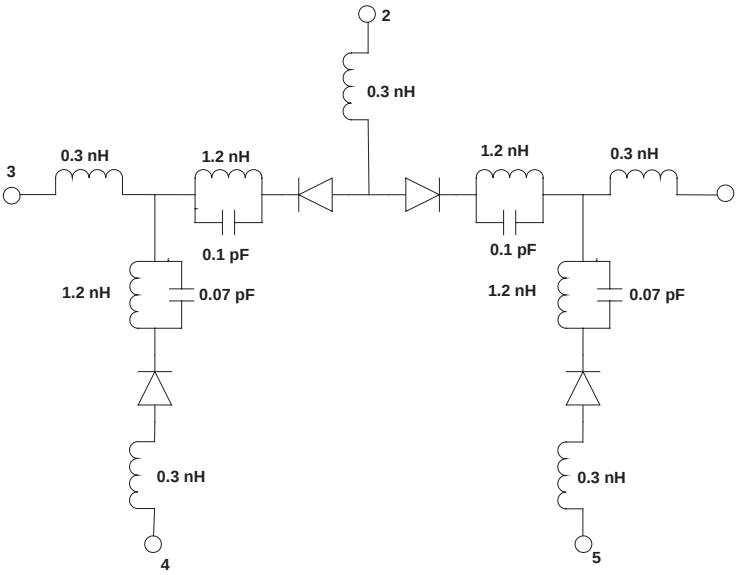


Figure 14. Sot-25 equivalent lumped circuit model

Notes:

[3] Voltage variable attenuator using Hsmp-3810 Diode" , Agilent EEsof Knowl edge Center.

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