Design of RF Attenuator Based on PIN Diode

Xinfa Miao[1] and Xiuhua Wang[2]
[1]School of Electronic and Information Engineering, Lanzhou Jiaotong University, Lanzhou Gansu 730070, China
[2]School of Automation Electrical Engineering, Lanzhou Jiaotong University, Lanzhou Gansu 730070, China

***Abstract*—RF attenuator has been widely used in analog and radio circuit. Designed a wideband attenuator using a surface mount device that including four PIN diode. The attenuation can be adjusted by the control voltage. The attenuator has good matching characteristic and linearity in 300kHz~3GHz. The structure of the attenuator is simple. The attenuator can be designed and made easily. The attenuator is suitable in some fields.**

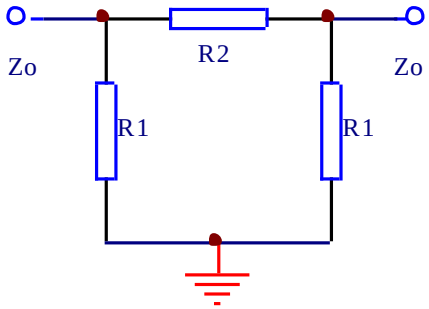
Key words-PIN diode; attenuator; HMSP3816

I. PREFACE

Attenuator can be used to control the signal level of the transceiver. It is usually used in the middle of two stage circuit that can attenuate the pre-stage's voltage to protect the device. It is also used to match resistance. Attenuator is widely used in the RF and microwave circuit. Such as GSM/CDMA/4G mobile communication network and the AGC circuit of the electronic countermeasure and wireless signal jamming system.

II. ATTENUATOR INTRODUCTION

If the attenuator need power supply, it is named active attenuator. Otherwise it is named passive attenuator. Passive attenuator can only be made by resistance. The attenuation and the calculation method are different if the resistance array is different. Using three resistance can design a PI prototype signal attenuator that the attenuation is fixed. It can get A=20log (K) attenuation by adjust the resistances and get the needed characteristic impedance. The formulae is shown in Figure I (K=Vi/Vo and proposed the input impedance and the output impedance is equal)[1].



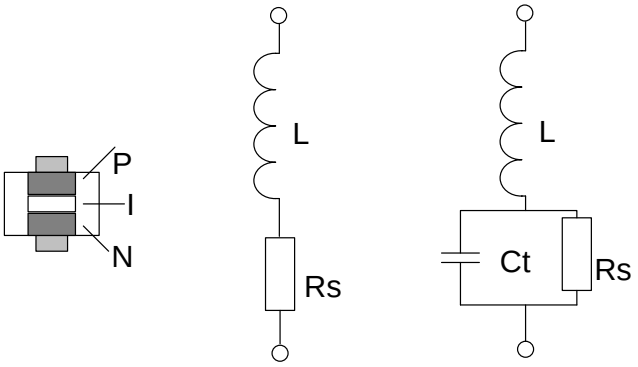
$$R_1 = Z_o(\frac{K+1}{K-1})$$

$$R_2 = \frac{Z_o}{2}(K - \frac{1}{K})$$

FIGURE I. BASIC PI PROTOTYPE ATTENUATOR

III. THE BASIC CHARACTERISTIC OF PIN DIODE

PIN diode includes three layers: highly doped P-type material and N-type material and the intrinsic layer which is in the middle of the P-type and the N-type. It is shown in Figure II.



(a) Faultage image of the PIN diode (b) Forward-biased(c) Reverse-biased

FIGURE II. STRUCTURE OF THE PIN DIODE

We can use low DC level to control high frequency high power RF signal by PIN diode. This diode is a low-distortion resistance that is controlled by current and has good linearity. PIN diode is widely used in RF microwave circuit including AM, attenuate, and level adjust function. High quality RF switch and attenuator can also be made by PIN diode.

IV. ATTENUATOR BASED ON PIN DIODE

In PI prototype network, PIN diodes are used as resistances which are controlled by current. We can design a attenuator which attenuation can be continuously tunable by three PIN diodes which replace R1 and R2 in Fig.1. The circuit will be asymmetric if R1 and R2 are directly replaced by three PIN diodes. So we must design a complex biased network to match it. Otherwise we use two diodes to replace R2 in Fig.1, so we get a symmetrical attenuate network and a simple biased network. Because PIN diode has parasitic capacitance, so it can make network isolated with other. The second, two diodes are series-wound so it can enhance the attenuation or double the highest working frequency *fmax*. The last, the two diode are anti-series connection, which can suppress even-order harmonic distortion. The schematic is shown in Fig.3.

In the test circuit, we use HSMP3816 as the main chip which is produced by Avago Co.,Ltd. HSMP3816 is a wideband, low insertion loss, high IIP3, quad pin attenuator in a low cost surface mount SOT-25 package. It provides a good match and flat attenuation over an extremely wide band from

300kHz to 4GHz. The SOT-25 packages gives a reduction in part count and takes up less space on board compared to multi package solutions. Four pin diodes in one package encourages performance repeatability for improved production yield at board level[2]. In Figure III, the V+ is fixed, we use Vc which is variable to control the attenuation of the input signal. C1 and C2 are the coupling capacitances of input/output. R1 and R2 is the biased circuit of the D1 and D2. All the value of the components are shown in the schematic.

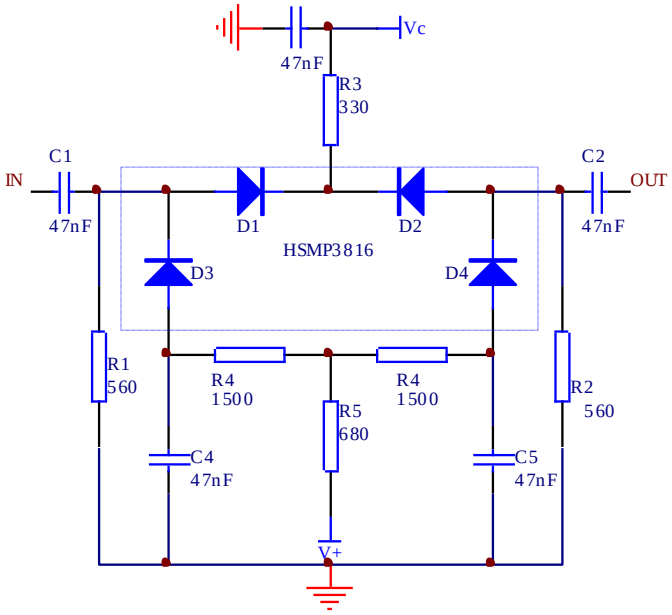


FIGURE III. ATTENUATOR BASED ON PIN DIODE

V. TEST RESULTS AND CONCLUSIONS

τ is the minority carrier lifetime of the PIN diode. The cut-off frequency of PIN diode is defined as $fc=1/2\pi\tau$, only when the working frequency is beyond 10*fc*, the model that PIN diode can be used as a variable resistance is accurate. The minority carrier of the HSMP3816 is about 1500ns, so *fc* is about 100kHz, this chip is suitable for design attenuator only above 1MHz. But Avago Co.,Ltd. has do some optimal design in this chip for special application. So this chip has good linearity above 300kHz.

Considering of price, this attenuator was implemented on FR4 PCB with a thickness of 1.0 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 HSMP3816, PCB, components and connectors[3]. In condition of V+=5V, Vc=0~15V,the bandwidth can reach 300kHz~3GHz.In condition of *f*=1GHz,V+=5V,Vc=0V,the typical value: IIP3=45dBm,Attenuation=38dB,Insertion Loss =-3dB,Return Loss=-22dB.The attenuation curve is shown in Figure IV.In this curve, the input frequency is 1GHz,the control voltage is from 1V to 11V. The result is fundamentally coincide with datasheet.

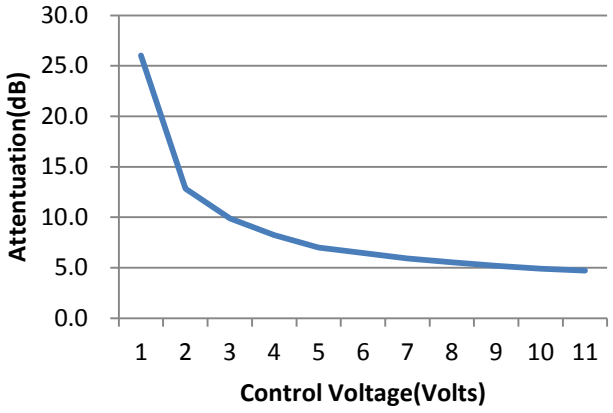


FIGURE IV. CURVE OF ATTENUATION

The experiment data shows: this attenuator's theory is clear, the quantity of the components is less, the technology of the PCB is simple, the bandwidth is wide, attenuating characteristic is good. The attenuator in this research was applied in AGC circuit of electronic countermeasure system and work well.

ACKNOWLEDGEMENT

This research was financially supported by the Province Science Foundation of Gansu (1310RJZA055,148RJZA055) and Lanzhou Jiaotong University Youth Foundation (2014001,2014039) .

REFERENCES

[1] BAI Ju-rong. Design of π Type Electronic Attenuator of PIN Diode[J].JOURNAL OF GUANGXI UNIVERSITY FOR NATIONALITIES (Natural Science Edition),2005,11(3):74-76.

[2] Avago Technologies. Quad PIN Diode π Attenuator 300 kHz to 4 GHz [EB/OL].http://www.avagotech.com/products/wireless/diodes/pin/hsmp-3816,2009.03.

[3] Avago Technologies. HSMP-3816 High Linearity PIN Diode Pi Attenuator Using a Diode Quad in Low Cost SOT-25 Package[EB/OL]. http://www.avagotech.com/,2010,9.