

Design of Adaptive Impedance Matching Circuit for Narrow Band Power Line Communication

Sridhar. S¹, Srikanth.S², Tamilarasan.R³, Vamsi.K⁴, Ashok Kumar. M⁵

UG Scholar, Department of ECE, Adhiyamaan College of Engineering, Hosur, Tamilnadu, India^{1,2,3,4}

Associate professor Department of ECE, Adhiyamaan College of Engineering, Hosur, Tamilnadu, India⁵

ABSTRACT: Power line communication is the technology that enables us to utilize electrical cables for transmitting our modulated data signals. The plc modem will be inserted at either ends of communication terminals which in turn is connected to cable that simultaneously transmit data and electrical signals. However it is obvious that data will not be allowed like conventional data cables. The reason is presence of white noise and abrupt load variations which affects the frequency selectivity and power received by the receiver. This design aims at efficient and simpler design of the transmitter filter part to deliver appropriate voltage according to changing loads. The design uses RLC-band pass filter and microcontroller for efficient impedance matching. We consider insertion loss issue in narrow band power line communication.

KEYWORDS: Narrow band power line communication, impedance matching, band pass filter.

I. INTRODUCTION

Power line communication had started to hold the researcher's attention as it is the only communication technology which is compatible with the wireless communication as both of them do not need extra wires to establish the communication between two points. The areas of research include efficient modulating technique, impedance matching issues etc. We concentrate on the latter. The purpose of impedance matching is to achieve maximum power transfer through the channel. Due to the time varying channel impedance, the fixed impedance matching circuits no more help us to achieve maximum power transfer. Many techniques have been proposed to achieve adaptive impedance matching but each of them have some disadvantages like bulky and costly circuitry. We propose a transformer-less, simple and reliable design to achieve the proper match between source and channel impedances for the purpose of efficient power transfer through the channel.

II. MOTIVATION

The power lines are not as suitable for transmitting the high frequency voltage signals. The reasons are presence of high noisy environment along the entire length of the cable. One more issue is time varying and location dependent impedances seen by the transmitter modem. The channel impedance will vary according to the load connected to it. Since the load value is time varying then the channel impedance is too time varying. So we propose a design of an adaptive impedance matching circuit for efficient power transfer. The art of design revolves around a famous theorem which states that the maximum power transferred to the load is exactly half of the input power and is achieved when the load impedance must be a complex conjugate of source impedance. We designed a component level adjustable band pass filter to attain our goal.

III. SYSTEM DESIGN

The design must fulfil our aim of maximum power transfer to the channel through impedance matching. Impedance matching is the process of making source impedance to be equal to load impedance in magnitude and it ensures that the reactance part of former is in out of phase with the latter. We consider the channel impedance to be purely resistive. Thus our work reduces to match the resistive parts of source and load impedances. To achieve this we make use of band pass filter whose component specification can be varied according to the necessity. This adaptability ensures our goal attainment. The channel (load) impedance is sensed through defined algorithm. Once we sense the actual channel impedance through the existing relationship between the components of filter and the load impedance we can determine the appropriate values for the maximum power transfer. The design consists of three parts signal generator part whose internal impedance is a part of source impedance. The middle part is band pass filter whose resistive and reactive parts constitute another part of the source impedance. The third part is load impedance part. Impedance matching occurs when the middle part matches source and load impedance part.

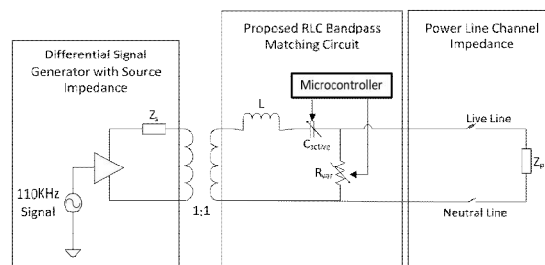


Fig 1: Proposed Adaptive Impedance Matching Circuit

A. FLOW OF INTERACTION BETWEEN COMPONENTS

The reliability of the system depends on the adaptability of the band pass filter components. In our design to show the practicality of the system we use microcontroller to feed the information of the load impedance to actual controller block. Upon receiving this information, the controller block changes the resistance value and capacitance value of the system. There will be a set of resistances in which each individual resistance is selected through the relays. The standard capacitors are connected in parallel through the microcontroller output pins. Based on the requirement, a set of capacitors are powered whereas remaining will be unpowered. If required capacitance is 12nF, the output pins 5 and 6 are triggered which will produce net capacitance of 12nF.

IV. ALGORITHM DESIGN

The source impedance can be given as

$$Z_s = jX + (R * Z_p / (R + Z_p)) \quad (1)$$

$$Z_p = (Z_s + jX) * R / (R + Z_s + jX) \quad (2)$$

Simplifying (1) and (2) for R and X

$$\text{We get } X = Z_s * Z_c / jR \quad (3)$$

$$R = Z_s * Z_c * Z_c / (Z_c - Z_s) \quad (4)$$

From the circuit to be shown below we can define $X = X_c - X_L$

$$C = 1 / (2\pi * f * X_c) \quad (5)$$

where C is desired capacitance for given Z_s and Z_p

Z_s is Source impedance

Z_p is Load impedance

R is desired resistance for given Z_s and Z_c

X_c is capacitive reactance

X is entire reactance of the circuit

Thus we get the relationship for the resistance and capacitor of the band-pass filter with the load and source impedance. This remains the basic concept governing the design.

A. CIRCUIT DIAGRAM

In the circuit diagram the signal source refers to the output of the modulator in the transmitter modem. The modulated signal will then be passed through the band pass filter which is denoted by RLC part of the circuit diagram. Z_p refers to the load impedance which is channel's impedance that varies according to the connected load.

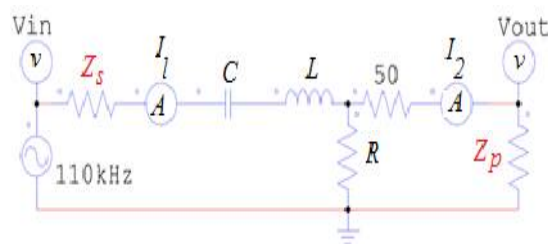


Fig 3: Circuit Diagram of the Design

B. TRANSFER FUNCTION OF THE BAND PASS FILTER

$$H(j\omega) = \left(\frac{V_{out}}{V_{in}} \right) = R / (R + j(\omega L - \frac{1}{\omega C})) \quad (6)$$

Using this transfer function we can analyse the frequency selectivity of the filter. Our choice of inductor as $5\mu H$ (micro Henry) will pass the frequency of range 110KHz which is in NB-PLC range.

V. PRACTICAL REALISATION OF THE DESIGN

The design is realized through two microcontroller block which communicate between them to produce the signal of desired power. The actual problem is time varying load which greatly affect the channel impedance. To practically show the variations in the load impedance we use one microcontroller to introduce the varying nature of load impedance. The microcontroller block will introduce various impedances one at a time to give the feeling of varying load impedance. This microcontroller is interfaced with other controller that varies component specification of the band-pass filter. There will be a set of resistors each connected to individual relays so that they can be individually placed inside the circuit corresponding to the load impedance. The capacitors are connected in parallel with each other. When a required capacitance is needed the parallel capacitors are appropriately triggered to produce the net required capacitance. The input is fed through the function generator. The output will be connected to cathode ray oscilloscope. There will be two outputs one indicates input voltage and other shows the output voltage. This can achieved by simultaneously using the two available channels of the CRO.

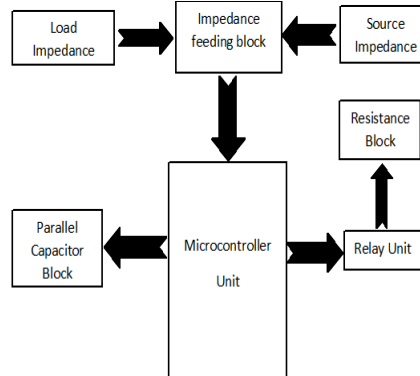


Fig 4: Hardware Interaction Flow

VI. RESULTS

The practical realisation of our design is done through simulation and experimental setup. The simulation is done by using two simulation tools PSIM (power simulation software) and Matlab. PSIM software gives the voltage drop across channel impedance for varying loads. Through which we can verify the maximum transfer to the load.

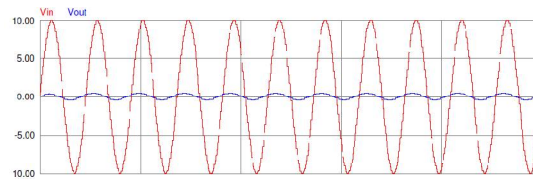


Fig 5: Voltage waveform for minimum load

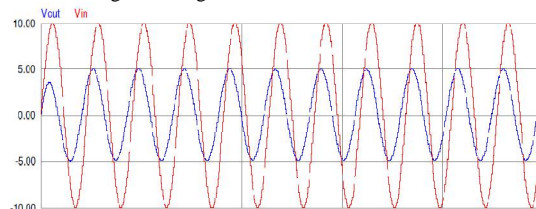


Fig 6: Voltage waveform for maximum load

The frequency response of the filter can be found by transfer function response for various frequencies. This is determined by plot between absolute value of transfer function and frequency. The plot shows that the gain is maximum around 110KHz range for both minimum and maximum loads.

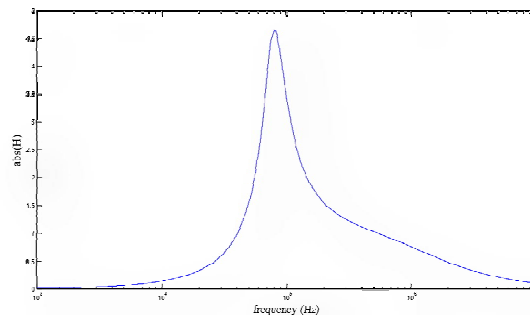


Fig 7: Frequency Response of the filter

Through microcontroller block and relay units the outputs were seen through the CRO for both minimum and maximum loads to prove the practical feasibility of the circuit.

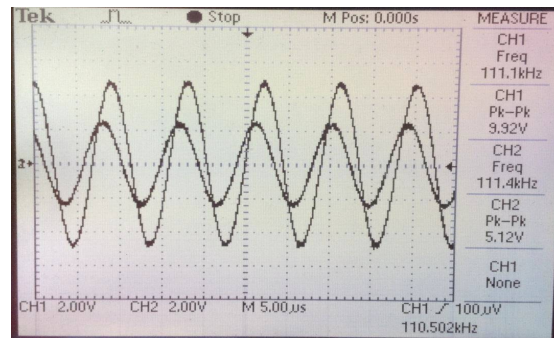


Fig 8: Voltage Waveforms for Maximum Load in CRO

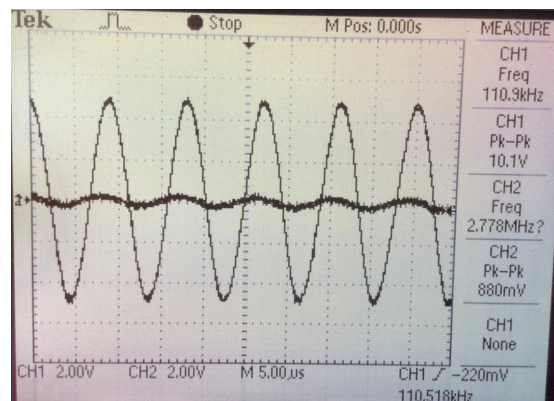


Fig 9: Voltage Waveforms for Minimum Load in CRO

VII CONCLUSION

The design is simple and easily adaptive to the varying load impedances ensuring the maximum power transfer to the load at all times. The design is simple because it does not use any bulky or costly components and is reliable as the components are easily tuned and accurately tuned to produce desired output. Thus the design provides reliable adaptive impedance matching for narrow band power line communication application.

REFERENCES

- [1] C.H. Lien, H.C. Chen, Y.W. Bai, M.B. Lin, Power monitoring and control for electric home appliances based on power line communication, in: Proceedings of Instrumentation and Measurement Technology.
- [2] Nima Taheri Nejad, Lutz Lampee, Shahriar Mirbbasi, An adaptive impedance matching circuit for vehicular power line communication.
- [3] Peter Nisbet, Minco He, Lian Zhao, Transformer-less impedance matching networks for automotive power line communication.
- [4] R.H. Scott, R. Bullock, Method and system for power line impedance detection and automatic impedance matching, US Patent, 6515485 (2003).
- [5] C.Y. Park, K.H. Jung, W.H. Choi, Coupling circuitry for impedance adaptation in power line communications using VCGIC, in: IEEE International Symposium on Power Line Communications and Its Applications, ISPLC 2008, Jeju Island, 2008, pp. 293-298.
- [6] D.M. Brown, W.E. Engeler, J.J. Tiemann, High frequency MOS digital capacitor, in: International Electron Devices Meeting, Washington, 1974, pp. 523-526.