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Practical Approach towards Earth-Wire based Communication System

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Abstract:
Background*: As discussed in "Concept of Earth Wire based Communication System" paper, published in IOSR Journal of Electrical and Electronics Engineering Volume 14, Issue 2 Ser. I (Mar. – Apr. 2019), page no. 72-74 gives the idea of implementation of communication system which uses earth-wire as a medium of transmission of signal from one point to another point in a given enclosed electrical wiring structure which is practically demonstrated in this paper as a unidirectional communication system working on two different floors of a buildings, houses, etc structure.*
Materials and Methods*: In this demonstrated project it consists of digital encoders, digital decoders, voltage regulators, relays, switches, wires, diodes, step-down transformers, leds and some RC passive components which makes an electrical control unit and TMT steel rods with cement, sand, gravel and water makes two floors representing civil structure (RCC Construction) which is commonly found.*
Results*: A unidirectional communication system which transmits a signal between earth-wire (Signal+) and steel-bar (ground/common) (used in Civil Construction) serially with 4 bits of data (Control Signal) and 8 bits of security/module selection making a 12 bits control signal.*
Key Word*: Earth-wire communication, Encoders, Decoders, unidirectional communication, Digital Communication*

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I. Introduction

Backbone structure of an electrical system is its earthing system which protects from any leakages of mains current due to any fault, as in any electrical wiring earthing wire is the most important part of electrification as it is responsible for conducting leakage current to earth potential through it in faulty condition which happens very less in day-to-day life makes the earthing wire most unused wire among other wires (Phase & Neutral in 1 Phase, RYBN in 3 Phase) of electrification providing a pathway to use it for communication purpose from any given points in a closed electrification wiring.

II. Materials And Components

Entire project has been divided into two main parts as firstly it consists of Electronics and Electrical section and secondly it consists of TMT bars, Concrete and Mild Steel Pipe (MS Pipe) Structure.

Electronics and Electrical:

This category plays a vital role in the working of project as it consists of all the components responsible to control the loads, carrier signals, power supplies, etc.

Main Functions are as listed below:

a) Isolation between Mains power and regulated low voltage power for internal circuits
b) Step down of Mains 230V to 12V, 5V regulated DC power with maximum current of 1A.
c) Fetching inputs from switches controlled by user
d) Processing the user selected data and conversion of parallel data into serial data
e) Amplification of control signal into power signal
f) Switching of mains power supply for the control of load connected to it.

Detailed Construction:

i. Mains Protection Unit:
It includes MCB and RCCB for the protection, as in most of the commercial as well as residential wiring contains MCBs and RCCBs for it protection which related this project's behavior and effect on the real application site.
- MCB – provides Over load and Short Circuit protection
- RCCB – provides protection against leakage of current

ii. Power Supplies:
It serves main two function in this project as it provides the conversion of Mains voltage to low voltage AC power as well as it Isolates the mains circuit and control circuit from each other.it includes components like:
- Step Down Transformer (230V AC to 12V AC)
- 1N4007 Diodes (Full Bridge Rectifier Configuration)
- 1000uF Capacitor (Smoothing capacitor)
- 0.1uf capacitor (Smoothing capacitor)
- LED (indication of power)
- Resistor (to limit the current for led)

iii. Voltage Regulators:
Its prime function is to convert the unregulated dc power into regulated dc power which can be utilize by the control circuits and other components. Basically, it comprises of two voltage regulators with some passive components like:
- 7812 – 12V voltage regulator with 1A or maximum current rating
- 7805 – 5V voltage regulator with 1A of maximum current rating
- 100uf capacitor (smoothing capacitor)
- 0.1uf capacitor (smoothing capacitor)
- Heat Sinks (for cooling of voltage regulators)

iv. Encoders and Decoders:
Main section of the project which performs many functions like fetching of user input data from switches, encoding the data, conversion of parallel data into serial data, decode the data, conversion of serial data into parallel data, checking of valid transmission between transmitter and receiver and output of logic level signal. Components include in this section are as follow:
- HT12E (HOLTEK company 12bits encoder)
- HT12D (HOLTEK company 12bits decoder)
- Resistor (for local oscillator circuit in encoder and encoder)
- Switches for input of data by user (Push button and self-latching switches)
- LED (for indication of valid transmission of data)
- DIP Switches (for selection of target address in both transmitter and receiver circuits)

v. Drivers:
It acts as the power amplifier stage between control circuit and relays as it amplifies the control level signal emitted from decoder and amplifies its voltage from 5V to 12V dc which can be used to drive the 12V switching Relays for the control of the mains load. 4 NPN transistor stage used to drive 4 relays. Components includes are:
- NPN Transistor "BC547"
- Resistors 1K
- LED (for indication of each relay status)
- 1N4007 Diodes, as Flyback diodes (protection of overvoltage and reverse discharge of relays)

vi. Relays:
Switching components used to break and make the connection between mains power and connected loads as they are connected in series with the load and mains power supply. Mainly

it consists of 12V Relay with 5A of maximum current at 250V AC followed by screw terminals for its connections with loads.

TMT bars, Concrete and Mild Steel Pipe (MS Pipe) Structure:

As the name indicated it consists of the materials related to the civil construction. It mainly serves two functions in this project as below:

a. Represent the actual scenario of the actual Commercial/Residential building (showcasing the two different floors in this project).
b. Providing the return path for the carrier signal for the control of load

It is divided into its three main components as listed below:

i. TMT Bars:

TMT stands for "Thermo Mechanically Treated" bars which are widely used in the civil construction are used for the representation of the two different floors, as for single floor structure the bars are cut and welded into rectangles shape like structure with one point of contact left open above the concrete level. Detailed specifications and other properties are as follow:

- Diameter of TMT bar used = 8mm
- Electrical resistivity = 1.0 x 1e-7(ohm/meter) or more (major part of TMT bar is iron)
- Yield Stress(N/mm2) = 430 – 490
- Carbon (C) content = 0.18 - 0.25
- Sulphur (S) content = 0.035-0.055
- Phosphorus (P) content = 0.035-0.055
- Sulphur + Phosphorus(S+P) content = 0.070-0.11
- Carbon Equivalent (CE) content = 0.26-0.37

Images for TMT Bars Structure:

(Figure2.1 TMT Bars Structure with MS Pipe)

ii. Concrete:

For providing the strength and base level for the floor concrete is used generally for all civil structure, so in order to replicate the practical scenario at the main application of this project for each floor concrete has been filled and solidified. Detail specification of the concrete are as follow:

- Grade of Concrete = M20
- Mix ratio = 1:1.5:3, mixture of cement, sand and aggregate in which one part is cement, 1.5 Part is sand and 3 part is aggregate
- Hardening time = 24 Hours

First floor has been concreted and hardened by 24 hours and after leaving a day gap second floor has been concreted followed by hardening time of 24 hours.

Calculation:

As two floors are identical some calculation regarding each floor are showed as below:

Mix Ratio = 1:1.5:3

Volume = 20cm X 14.5 cm X 3 cm

= 870 cm^3 or 0.00087 m^3

Volume of dry Concrete = 1.54 to 1.57 times Volume of wet concrete.

Now calculations are as follows for 1m^3 (assumed) of Concrete work

Ratio Sum = 1+1.5+3 = 5.5

Shrinkage or safety Factor = 1.57
So Total volume of wet concrete required is: 1.57 m^3
Volume of cement = (1/5.5) x 1.57 = 0.285 m^3
Volume of sand Require = (1.5/5.5) x 1.57 = 0.471 m^3
Volume of aggregate (broken stones) required = (3/5.5) x 1.57 = 0.856 m^3
For 1m^3 of M20 (1:1.5:3)
Density of Cement = 1440 Kg/m^3
∴ 0.285 x 1440 = 410.4 Kg
Density of sand = 1442 Kg/m^3
∴ 0.471 x 1442 = 679.182 Kg
Density of aggregate (broken stones) = 1520 Kg/m^3
∴ 0.856 x 1520 = 1301.12 Kg
Materials Required for 0.00087 m^3 are as required:
Cement [0.00087 x 410.4] = 0.357048 Kg or 357 Grams
Sand [0.00087 x 679.182] = 0.59088834 Kg or 590 Grams
Aggregate (broken stones) [0.00087 x 1301.12] = 1.1319744 Kg or 1.132 Kg
Images for concrete floor process:

(Figure 2.2 Concrete Structure on TMT Bars and MS Pipe)

iii. Mild Steel Pipe (MS Pipe) Structure:
Mild Steel Pipe structure provides the strength to the two concrete floors of a project structure inside which square welded TMT bars are placed and the ends are welded with the MS Pipe to provide strength and base for each floor. It serves two main functions as stated below:

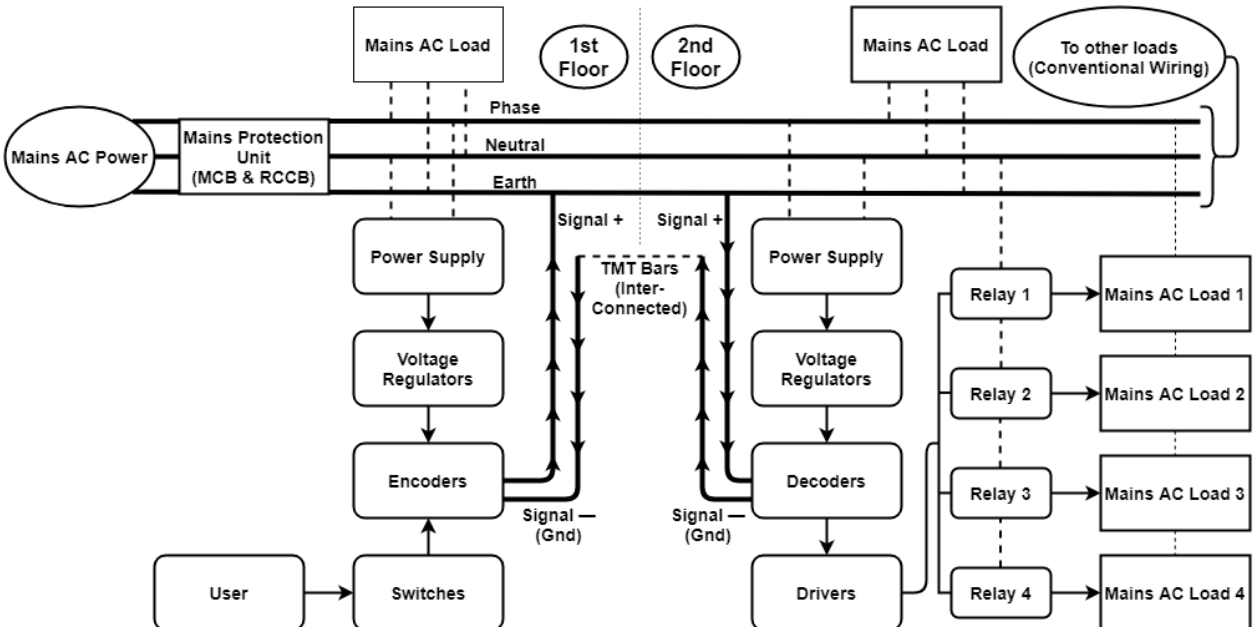
- Mechanical Strength and support to the floor of the concrete structure
- Continuity between the floors (as in practical civil construction TMT bars are itself joined together in whole structure where MS Steel pipes are absent)

Construction details are as follow:

- Material of each pipe = Mild Steel with low Carbon content
- Black Oxide Coating for protection against rusting/Corrosion
- Distance between each concrete floor = 18 cm
- Total length of Each pipe = 30 cm

III. Working

Uni-directional communication between the two floors of any civil construction is demonstrated in this project providing the 4 channel ac mains load control using this circuit. Block diagram is showcased as below providing the overview for function of all the components and its role in this project:



(Figure 3.1 Working Block Diagram)

1. Mains Protection Unit consists of the MCB and RCCB which provides protection against Over load, Short Circuit and Leakage of any Current from mains circuit respectively which is present in any type of electrification in commercial as well as residential wirings. It is also been mandatory to install for protection in any type of electrification rules implemented by government policies.
2. Mains Ac Loads are placed with Phase, Neutral and Earth wire connected to them as the primitive electrification practice describes and there is not any kind of change for the implementation of this demonstrated circuit in this project.
3. Power Supply Section input is connected to the mains 230V AC which is converted into 12V and 5V AC with peak current of 1A with the help of Step-Down transformer which also provides isolation between mains circuit and step down voltage circuit connected to its secondary side. 1N4007 Diodes with Full Bridge configuration converts 12V and 5V AC voltage into DC voltage followed by the smoothing capacitors of 1000uF and 0.1uF which removes spikes from the rectified dc voltage and increase stability of voltage level under load.
4. Unregulated 12V and 5V DC is supplied to 7812 and 7805 linear voltage regulators which provides stable 12V and 5V regulated DC power followed by smoothing capacitor of 100uF and 0.1uF. Powe supply indicators are also provided which indicates the availability of supply with simple current limiting resistor and LED.
5. Regulated 5V DC power is supplied to Encoder named HT12E which is 12 bit encoder under which it fetches the Address bits and Data bits from the user selected switches and converts parallel data into serial data in 12 bits pumped into earth wire of the mains electrification circuit.
6. At the receiver side Power supply and voltage regulator stage performs the exact same function as discussed in 3rd & 4th points mentioned above.
7. 12 bit serial signal in the earth wire is collected by the HT12D decoder which return path is provided by connection made if ground with TMT bars at each floor which are electrically conductive and interconnected with each other in a whole structure.
8. When the address bits set by the user in the encoder matches with the receiver address it reads the data bits send to it via earth wire and serial data of the received signal is converted int parallel data at logic level voltage(5V).
9. Logic level signal's power is amplified by the driver stage which consists of BC547 NPN transistor with some passive components like base current limiting resistor led and resistor for relay status indication as well as flyback diode (1N4007) to prevent reverse voltage discharge of relay and overvoltage spikes by relay coil connected to it.
10. Amplified control signal by the driver is supplied to the relays which makes and breaks the connection of mains ac load with mains power (Phase and neutral) which makes the connected load remotely operated by the user with the transmitting circuit as discussed.

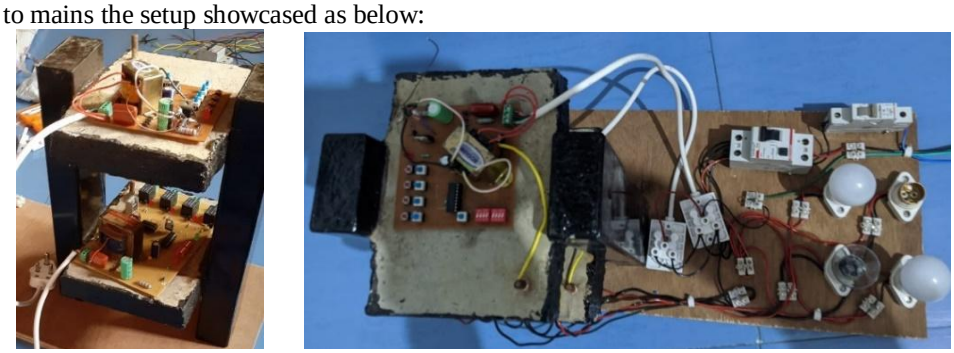
As the above steps makes clear about the methodology and working of the proposed prototype under which 4 individual mains ac load are controlled and remotely operated by the user in a civil structure which utilize earth wire of the electrification as the carrier between the transmitting point and receiving point although they are located at different floors or any other point in a civil structure.

IV. Result

While carrying out the practical various measurements and approaches were made in order to test out the different scenario which might occur at the real site of application. Some assumptions and conditions were assumed which are discussed below:

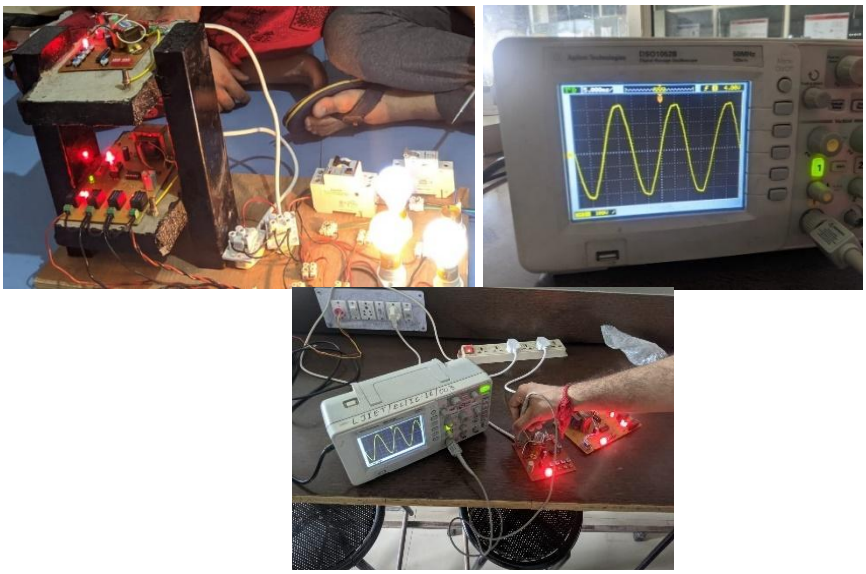
- Mains voltage monitored throughout practical lies between 236 V AC to 245 V AC
- Connected mains load at each floor varies between 250 Watts to 600 Watts
- Connected mains ac load on each relay is 40 Watts (lamp load)
- Distance between transmitter and receiver is 20 cm
- Resistance between transmitter and receiver measured is < 1 ohm
- RR Kabel 1.5 sq mm wire (16AWG)
- HTC DM-830L Digital Multimeter for measurement of Voltage and Resistance
- ELECTROPRIME 91C4 DC Analog Ammeter
- Anchor Double Pole MCB (2P) at 20 Ampere
- RCCB of L&T Switchgear for 25A 2 Pole and 30mA
- 29° C Temperature is maintained during practical

As discussed above every apparatus were connected for execution of practical at which without connecting to mains the setup showcased as below:



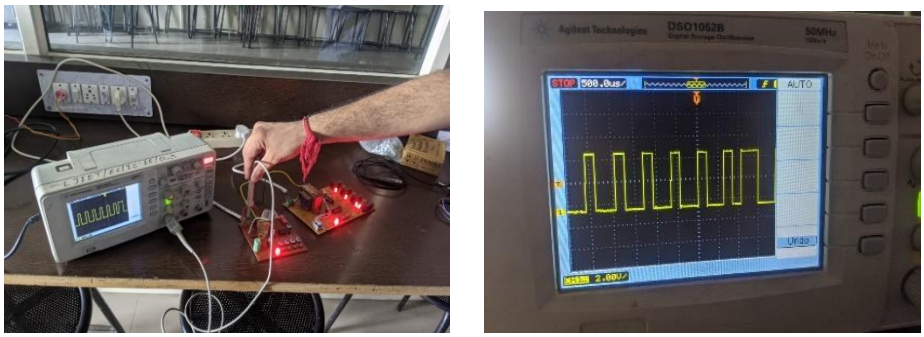
(Figure 4.1 Project Setup with Transmitter and Receiver circuits along with mains load connected)

When Mains voltage is applied to the setup the reading of various parameters like signal transmission voltage, mains voltage, power consumption, etc are noted for further evaluation.

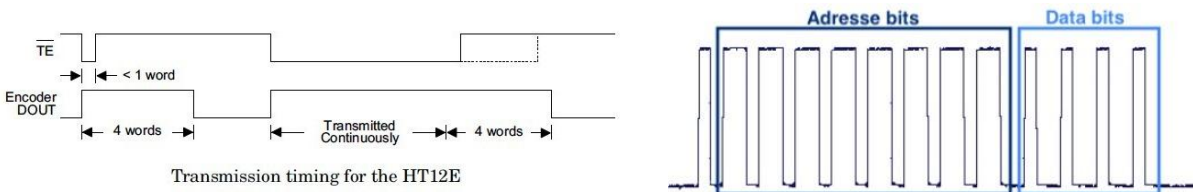


(Figure 4.2 Project Setup Connected to Mains AC Power)

As discussed above the transmission of signal is carried out in a 12 bit serial data which is shown theocratically as well as practically performed and obtained results are as follow:



(Figure 4.3 Project Setup hooked on DSO for signal observation)



(Figure 4.4 Transmission of address and data bits from transmitter to receiver for HT12E & HT12D)

Among the 12bit of output first 8 bits represent the address bits which plays the essential role in this project as user can select between multiple receiver module connected in a single mesh network in a closed civil structure and its electrification.

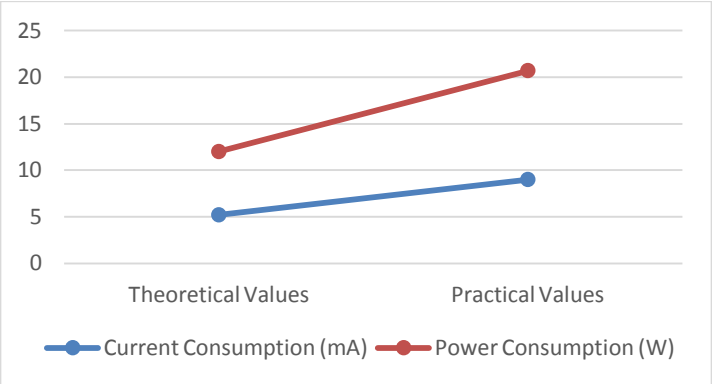
Last 4 bits of the signal represent the status of the output which is controlled by the user in order to switch ON/OFF the mains ac load connected to the relays at receiver side. When the valid transmission signal is not received by the receiver module it latches the outputs in its previous state and when valid transmission signal is received all the outputs of the receiver get update by the data bits coming from the transmitter module at that particular instant and again when signal is not present it latches the output in its previous data states.
After performing the practical some theoretical values and practical values are as compared below:

Title	Theoretical Values	Practical Values
Current Consumption	0.052A	0.09A
Signal transmission voltage	2.6V	2.46V
Resistance between Transmitter and Receiver	< 1 Ohm	1.01 Ohm
Power Consumption	12 W	20.7 W

(Table 4.1 Comparison of Theoretical and practical values of current, signal voltage, resistance and power)

Note: Due to the limitation of the measuring instrument used for measuring resistance (Multimeter) the readings below 1 ohm are not displayed and measured which indicated the least value of 1 ohm with 0.1% of error.

Comparison between the current consumption and power consumption of its values calculated theoretically and actual practical values are represented as shown below:



(Figure 4.5 Graphical representation of theoretical and practical values of Current and Power)

While using this module as mains protection devices like MCB and RCCB are connect are not tripped as return path of the signal is provided by TMT bars as well as any kind of malfunction is not observed in mains or control side under the continuous test period for 28 days with at least 4 times switching a day.

V. Conclusion

Unidirectional communication between the two points of an enclosed civil structure and electrification of mains line in it where earth wire serves as a carrier medium between the transmitter and receiver modules with return path of the signal fulfilled by TMT bars of the civil structure provides the control of 4 channel mains load control by user along with its selection of receiver module provides the multiplexing of the control points from single transmitter module.

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