EMBEDDED OPTICAL COMMUNICATION SYSTEM FOR AN OPTICAL COMPUTER

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Abstract : Computer Scientists believe that Moore's law will come to an end by the year 2020 i.e. we will reach a saturation stage where no more transistors can be placed on a given chip. The solution can be to augment data flow rate or in other words, change the medium of information transfer within the computer. We have been using electrons to compute. To decrease the compute time and data flow rate, a fast medium is required. The fastest possible medium is Light. While this paper focuses on the optimization of data flow technology using Light as a medium, many researchers are developing optical transistors. By synthesizing these components we shall have a complete optical computer in the near future capable of computing quadrillions of operations per second.

***IndexTerms* - Optical Computer, Embedded transmission, Optical fiber, Li-Fi, Visible Light Communication, Optical Computer Bus.**

I. INTRODUCTION

Since the inception of the digital age, we have seen a flood of innovations focused to reduce the size of the computers, increase their memory, reduce the computing time and use minimum energy to compute results. Gordon E. Moore predicted that the number of transistors on a chip will double every two years.[1] Until now the Moore's law has held good and transistors have been developed in the 10-14 nm range. But, Moore's law is expected to be non-feasible after 2020 as we will reach a critical transistor size of about 5nm. At this level, quantum effects come into play and the electron in a transistor will just tunnel through its gate. Hence, the transistor always stays on.

A solution to this problem can be to optimize data flow rate inside the CPU as well as between the CPU and the memory, peripheral devices etc. Currently copper traces are used to transfer data inside the CPU and external buses are used to transfer data between the CPU and the memory, peripheral devices etc. Electrons serve as the medium of data transfer in all the above applications. To increase the data flow rate, the speed of the medium must be increased. The fastest possible medium is Light. Light can be used to transfer data without noticeable losses.

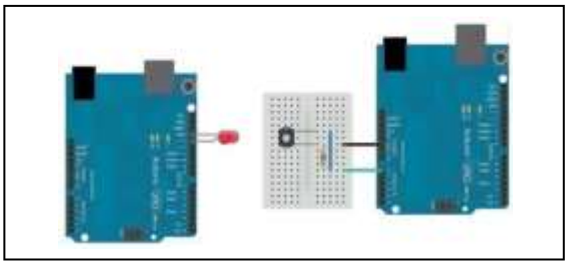
Light-Fidelity (Li-Fi) system provides transmission of data through illumination by sending data through an LED light bulb. Li-Fi uses Light Emitting Diodes (LED) which have high modulation bandwidth and energy efficient illumination.These LED's have high switching speeds that enable them to modulate according to the stream of bits that are sent. This transmission takes place in a parallel stream such that more data is being transmitted simultaneously.

Li-Fi utilizes the visible light portion of the electromagnetic spectrum (380 nm to 780 nm). Thus, it has 10,000 times more space available thus more available bandwidth is present. Theoretically, it can reach the speeds up to 224 Gbps. [2] Li-Fi was developed for a wireless usage. But, this technology can be embedded in a computer to transmit data. The copper traces can be easily replaced by embedded optical fibers which can carry the light beams to the specified location decreasing the noise considerably.

II. DESIGN METHODOLOGY

2.1 Experiment for transferring 1-bit data

An experiment was conducted to examine the feasibility of the transmission system. An Arduino UNO board was used to transfer and receive single-bit data through an LED and a Photodiode connected as shown.



Further the assembly was kept in a dark room to remove noise arising out of the ambient light. The following code was run to send data bits.

```
int ledpin = 13;
int iter = 0;
void setup()
{
  Serial.begin(9600);
  pinMode(ledpin,OUTPUT);
}

void loop()
{
  for (iter = 100; iter >= 0; iter--)
  {
    digitalWrite(ledpin,HIGH);
    digitalWrite(ledpin,LOW);
  }
}
```

code used to send data bits

The photodiode values received by the Arduino range from 0 for no light to 1023 for fully bright light. Therefore, code used in the experiment normalizes the analog values received by the photodiode between the range of 0V to 5V. If the induced voltage is greater than 3.5V the data-bit is read as 1 and if the induced voltage is between 0V and 3V the data-bit is read as 0. The experiment gave a positive result with zero data loss.

```
int lightsensor = 0;
int logic = 0;
float voltage = 0;

void setup()
{
  Serial.begin(9600);
  pinMode(A0,INPUT);
}

void loop()
{
  lightsensor = analogRead(A0);
  voltage = lightsensor*(5.0/1023.0);

  if(voltage >= 3.5)
  {
    logic = 1;
  }
  else
  {
    logic = 0;
  }
  Serial.print(logic);
}
```

code used to receive data bits

2.2 Designing Transfer Mechanism for Optimized Transfer Speed

SMD LEDs can be programmed to deliver pulses in the range of 50 picoseconds to 800 picoseconds. This time is more than enough for a photodiode to change its output from 0 to 1 or vice-versa.[3] In my calculations, I assumed the LED pulse to be 50 picoseconds long. For logic 0 the LED stays off, For logic 1 the LED pulsates once. Including the latency due to travelling in the optical fiber and induction of current in the photodiode, one bit of data is transferred in 100 picoseconds through a single LED and Photodiode pair.

The following calculation gives the bit-rate:

$$1 \text{ ps} = 1 * 10^{-12} \text{ s}$$

$$\text{Bit-rate} = 1/(1 * 10^{-12}) \text{ bits/s}$$

$$\text{Bit-rate} = 10^{12} \text{ bits/s}$$

$$\text{or } 125 \text{ GB/s}^{**}$$

Hence, theoretically a single LED and Photodiode pair can transfer 125 Giga-Bytes of data in just one second. Since, most computer buses have a comparatively less speed. Therefore, only two pairs of LED and Photodiode are sufficient for dual channel simultaneous transfer of data between two components.

***(Here it is assumed that the LED and photodiode are kept about 1cm away. Since light travels at about $3x10^8$ ms^{-1} therefore, out of the 100ps required to transmit one bit, 50 ps are consumed by the LED to pulsate and the remaining 50ps are consumed by the light beam to travel through the optical fiber and induce current in the photodiode. For every 1cm approximately 30ps are consumed by the light beam to travel through the optical fiber.)*

The BUS can be designed now. An optical fiber of the dimensions of a copper trace is used to connect an LED and a photodiode. At either ends the LED and photodiode are soldered such as to face the core of the optical fiber. The fiber is embedded in an IC chip just like a copper trace.

The bus drawn below is a dual channel 1-bit bus. At any instant of time data can be transferred simultaneously from both ends one bit at a time. As stated above the bit-rate is more than enough to support data transfer in 32-bit or 64-bit computer systems. For an even more enhanced bit-rate N bus-pairs can be cascaded together to multiply the bit-rate by N-times.

Bit-rate = N*125GB/s

where N is the no. of bus-pairs.

proposed design of a dual-channel optical bus

III. Conclusion and Future Scope

In this paper, an off-the shelf LED and photodiode were used to transmit and receive data, respectively. It is believed that SMD LEDs will provide short pulses as stated in the paper and SMD Photodiodes will function more effectively.

The smallest SMD LED package has been released by Kingbright Electronic Europe GmbH [4]. With such small sizes the bus size is reduced significantly and manufacturing cost reduces. Since, glass/plastic is relatively cheaper than silicon/copper, the bus will be inexpensive compared to copper traces. Therefore, this optical bus is cheaper and more efficient than any of the available computer buses.

Researchers are working towards the realization of an optical computer which uses Light as the computing medium instead of electrons. A single nano-particle transistor has been developed by the researchers at MIT [5]. With the advent of such devices computing speeds will soar with the decreasing size of IC chips. One day we will surely have a computer in our pockets with an exponentially increased computing power of today's computers.

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