3rd IEEE Workshop on Optical Wireless Communications (OWC'12)

DESIGNS OF A FREE-SPACE WHITE-LED MASS-STORAGE TRANSCEIVER FOR SD-CARD FILE TRANSFER

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Outline of Presentation

- Objective
- Background
- PPM SD-card Transceiver
- PWM SD-card Transceiver
- Performance
- Conclusion
- Future Work

Objective

- To test the feasibility of a VLC mass-storage device that operates under a standard file system.
- A VLC Flash drive is contactless and will become one of the important devices in the future white-LED indoor wireless network.
- Two transceiver prototypes (PWM and PPM) have been built for file transfer between SD card and PC. Both operated successfully.

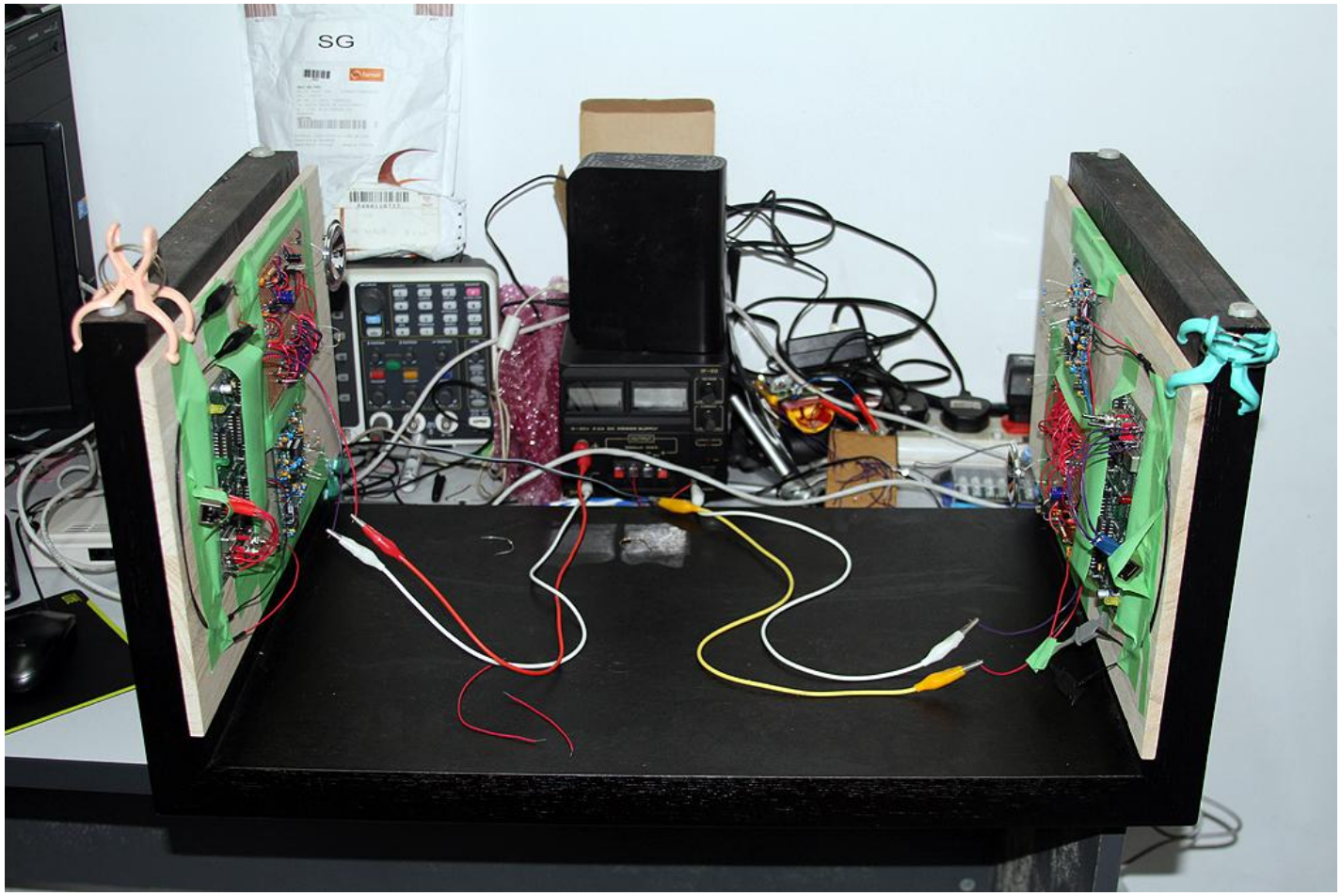
Background

- VLC technology descends from IR technology.
- Before Bluetooth, we used to have cell phones that have IR transceivers.
- IBM and Intel: developing chips with optical interconnects.
- High possibility of computer motherboards with optical input/output (I/O) ports in the near future.
- Although there was no previous investigation on VLC circuits for SD card file transfer, there are some previous works on VLC based on serial communication which are very useful.

Ronja (1998) http://ronja.twibright.com

- 10BaseT - RS422
- 10 Mbps
- Open source schematic

Ronja Replica (2009)



Serial Data Link - Early Version

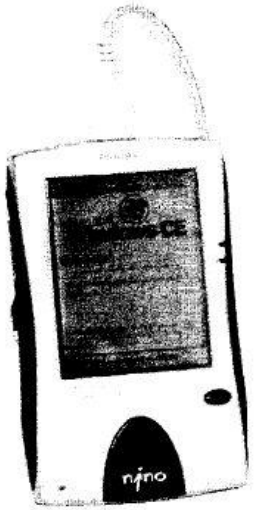


Figure 2 Multimedia Information Device

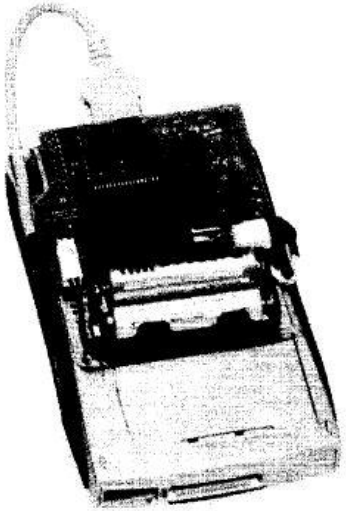


Figure 3 Receiver Module

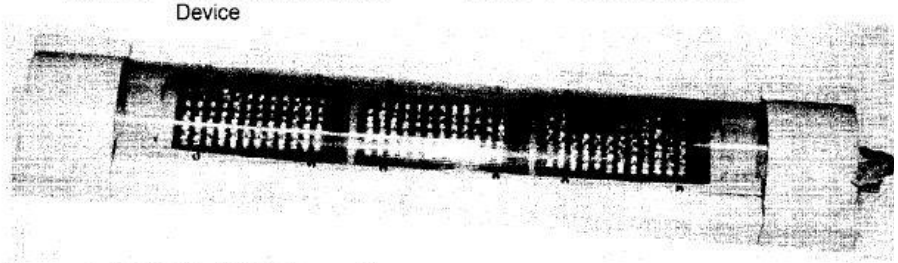
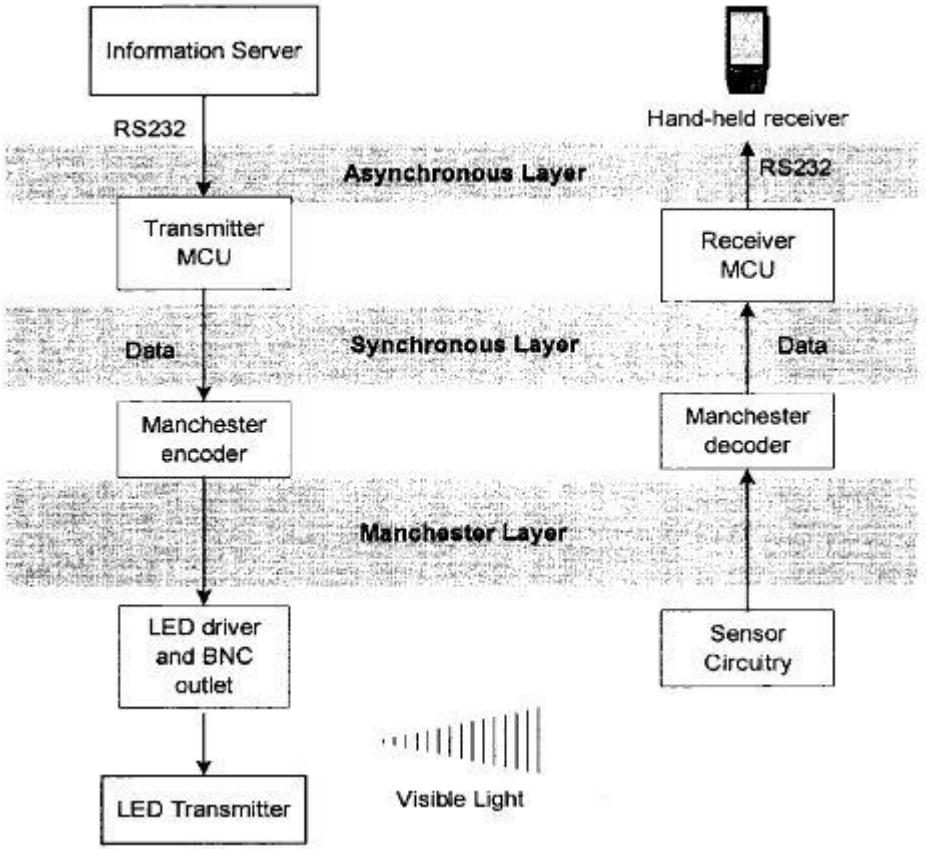
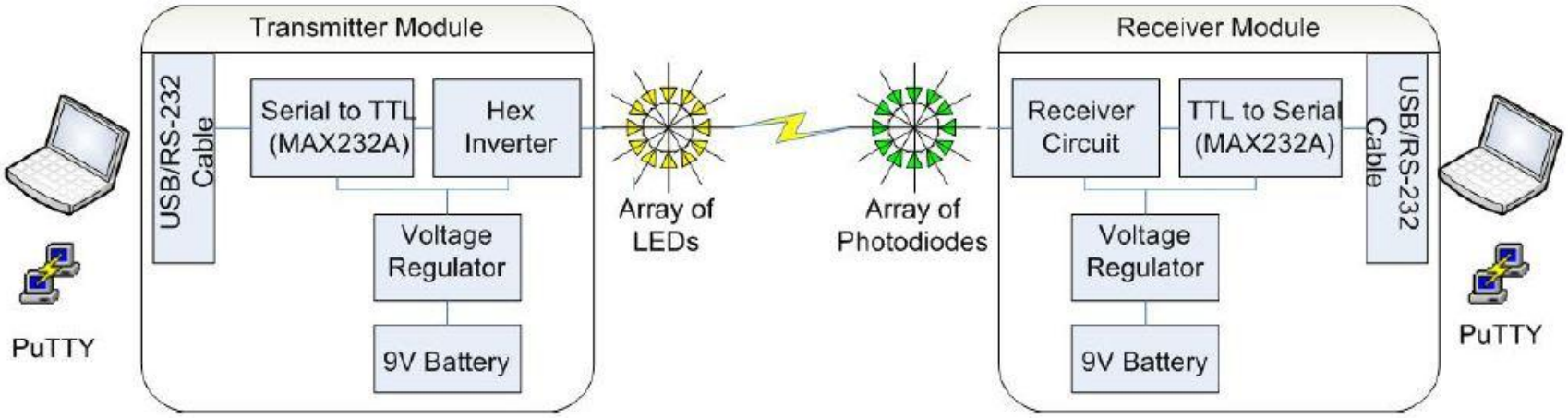


Figure 4 Visible Light LED Transmitter



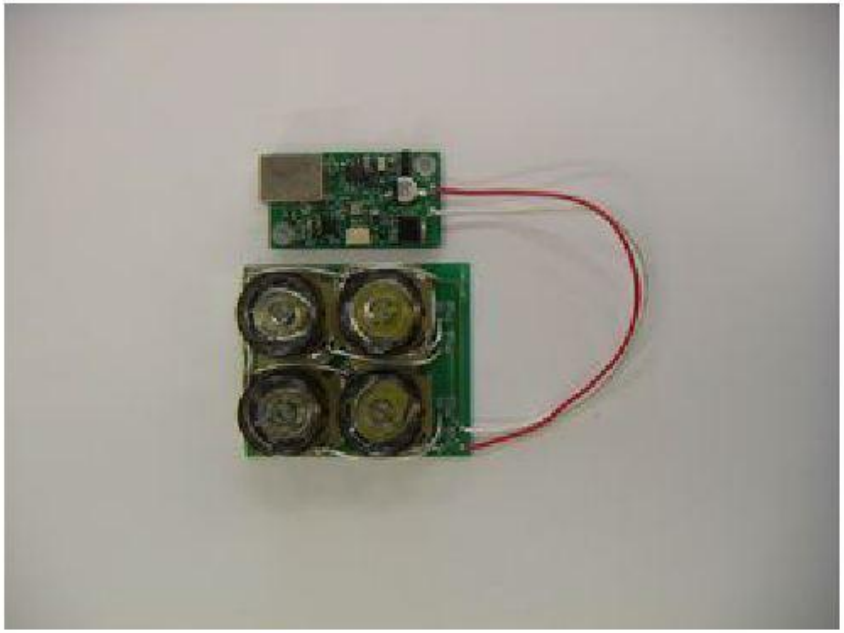
G. Pang and G. Poon, "A Portable Multimedia Information Device in a Wireless Optical Data Link", *IEEE Transactions on Consumer Electronics*, vol. 47, no. 1, pp. 87-95, 2001.

Serial Data Link - Later Version



T. D. C. Little, P. Dib, K. Shah, N. Barraford, and B. Gallagher, "Using LED Lighting for Ubiquitous Indoor Wireless Networking", *IEEE International Conference on Wireless & Mobile Computing, Networking & Communication (WIMOB 2008)*, pp. 373-378, 2008.

Nakagawa Laboratories, Inc.



(a) transmitter unit

(b) receiver unit

http://www.naka-lab.jp/ecsite_e/index_e.html

The *Commulight* System

- Outstanding Technology Co. Ltd, Japan.

The *TR01* visible-light receiver is plugged into the USB port of a smartphone to receive information signals from ceiling lights.

http://www.houseofjapan.com/electronics/visible-light-communication-devices-ready-for-commercialization

Device and Storage Media

Device	Storage Media	Local CPU Interface to Media	Removable Media?
Hard drive	Hard disk	ATA	No
CD drive	CD	ATA + ATAPI	Yes
DVD drive	DVD	ATA + ATAPI	Yes
Flash drive	Flash memory	Local CPU data bus	No
Flash-memory-card reader/writer	Flash memory	SPI, MultiMediaCard bus, SD-Card bus	Yes

J. Axelson, *USB Mass Storage: Designing and Programming Devices and Embedded Hosts*, Lakeview Research, 2006.

SD (Secure Digital) Memory Card

- Developed by Matsushita, SanDisk, and Toshiba
- has a manual write-protect switch.
- supports additional commands:
  - Determine the type of card and memory capacity
  - Command the card to use a different voltage and different clock speed
- Widely popular – gaming consoles, cell phones, cameras
- Simple interfacing hardware, low power, full duplex

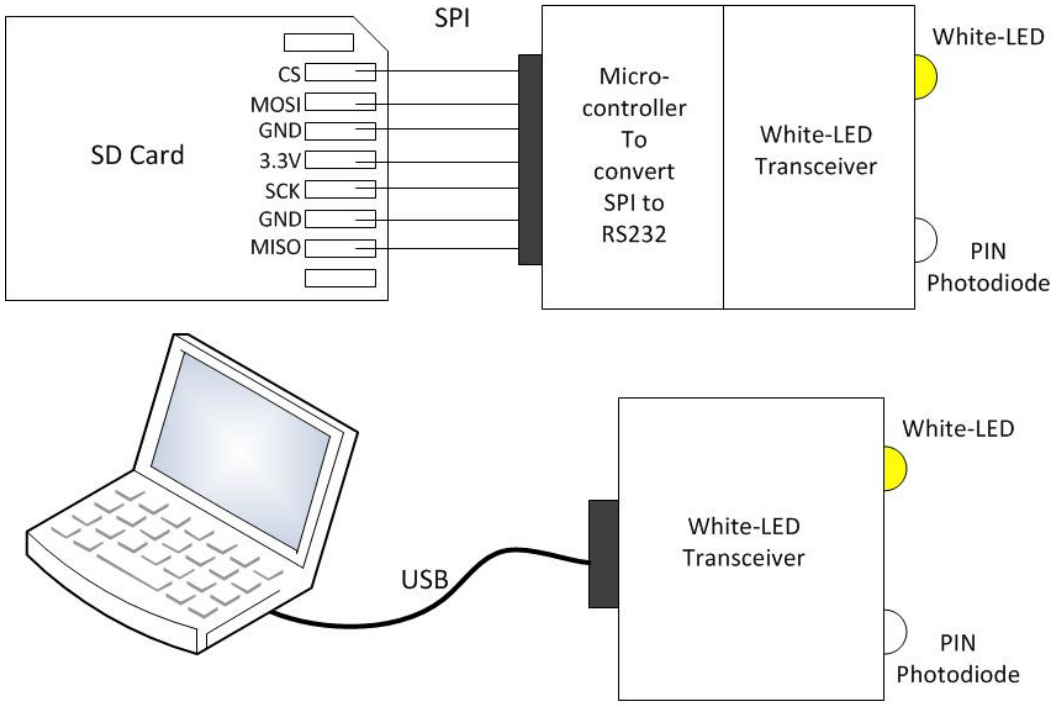
SD-Card Storage Media

Card	SD Card	miniSD Card	microSD Card
Sponsor	sdcard.org		
Physical Size (mm)	32 x 24 x 2.1	20 x 21.5 x 1.4	11 x 15 x 1
Pins	9	11	8
Interface	SD Card bus, SPI		
Data Bus Width (bits)	1, 4		
Maximum Data Transfer Rate (Mb/sec.)	100 (SD Card bus); 25 (SPI)		
Maximum Clock Speed (Mbits/sec.)	25		
Power Supply (V)	2.7-3.6 or 1.6-3.6(LV)		
Security	support for digital rights management		
Write Protect Switch	optional	no	no
Specification Cost	Membership @$1000/year		
Licensing Fees and Royalties	Host/ancillary product license for $1000/year, available to members only		

J. Axelson, *USB Mass Storage: Designing and Programming Devices and Embedded Hosts*, Lakeview Research, 2006.

SPI (Serial Peripheral Interface)

- Output from HOST – SCLK and MOSI
- Output from SLAVE – MISO
- HOST controls a unique chip-select (CS) output for multiple SLAVE connections.

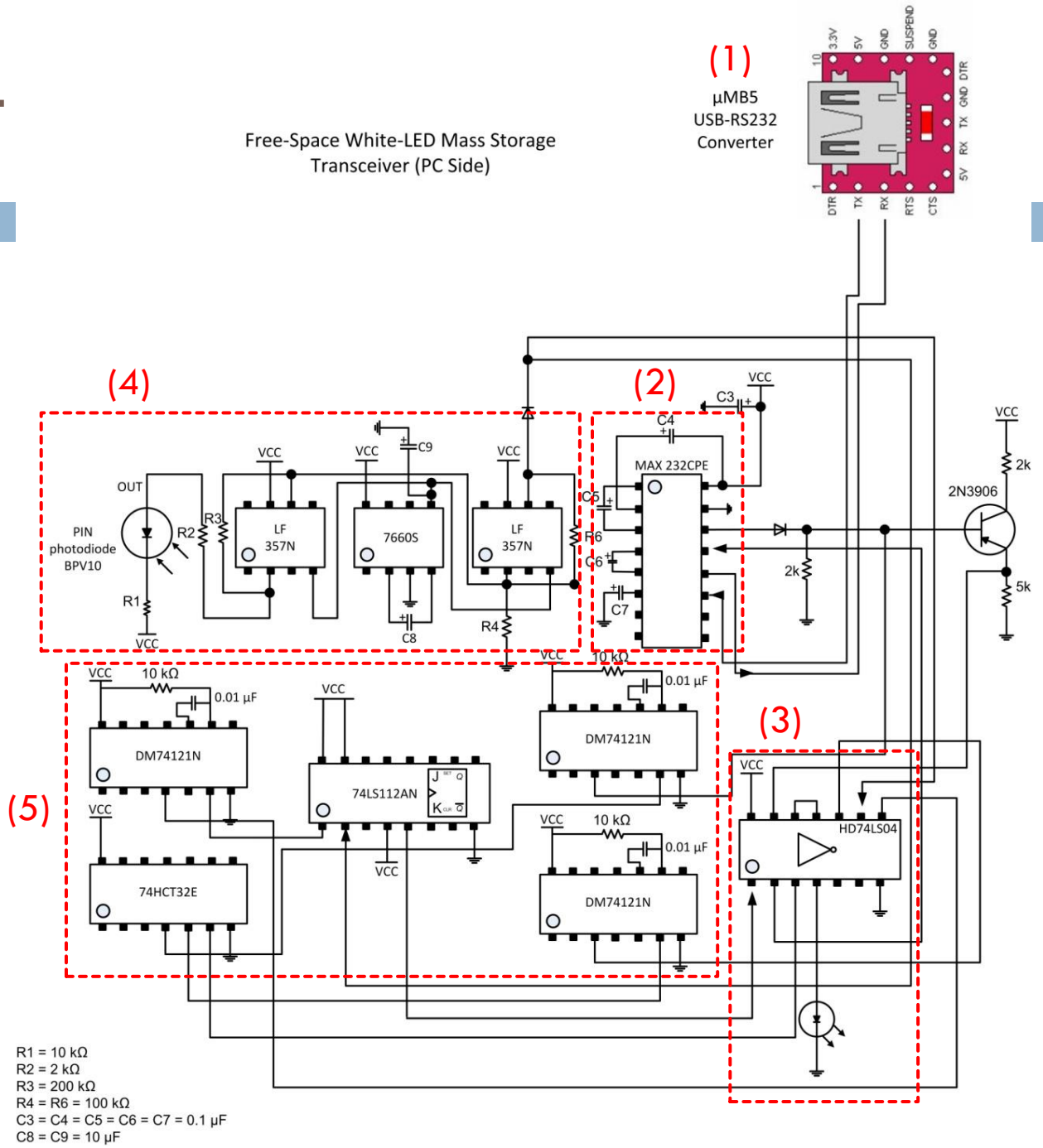


More information on SPI at http://www.eeherald.com/section/design-guide/esmod12.html

PPM Circuit

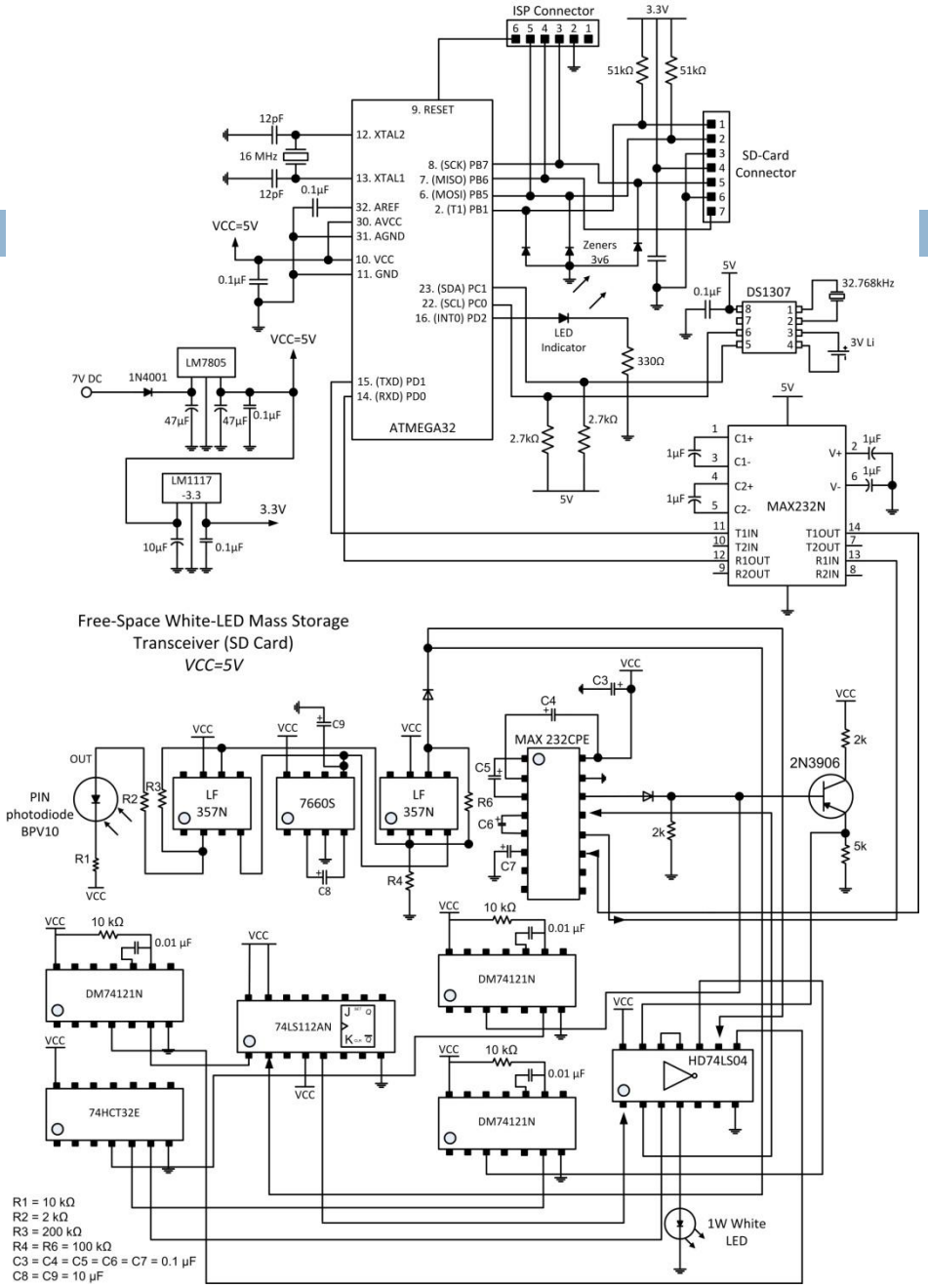
PC-side

1. Interface to PC (USB-RS232)
2. Line driver/receiver (RS232-TTL, basically level shifting)
3. LED driver
4. Receiver front end
5. Logic (multiplex/demultiplex or modulate/demodulate)

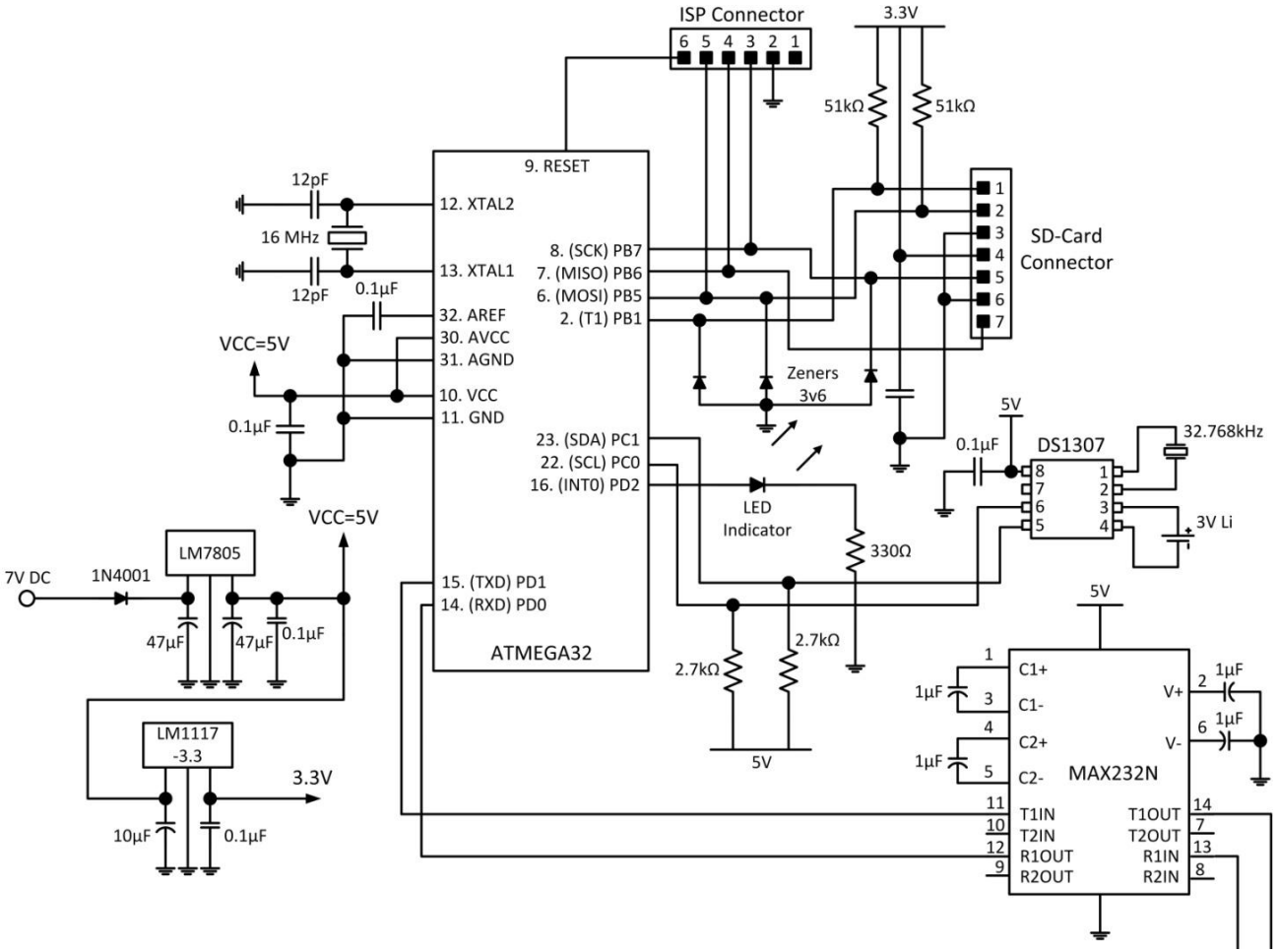


PPM Circuit

SD-card side



SD-Card interface schematic

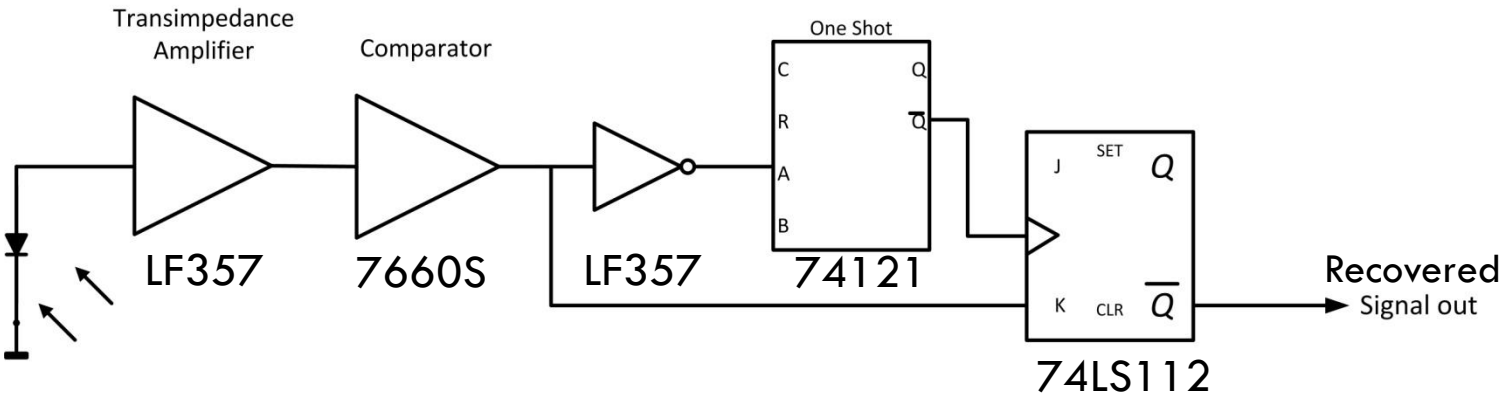


http://www.dharmanitech.com/

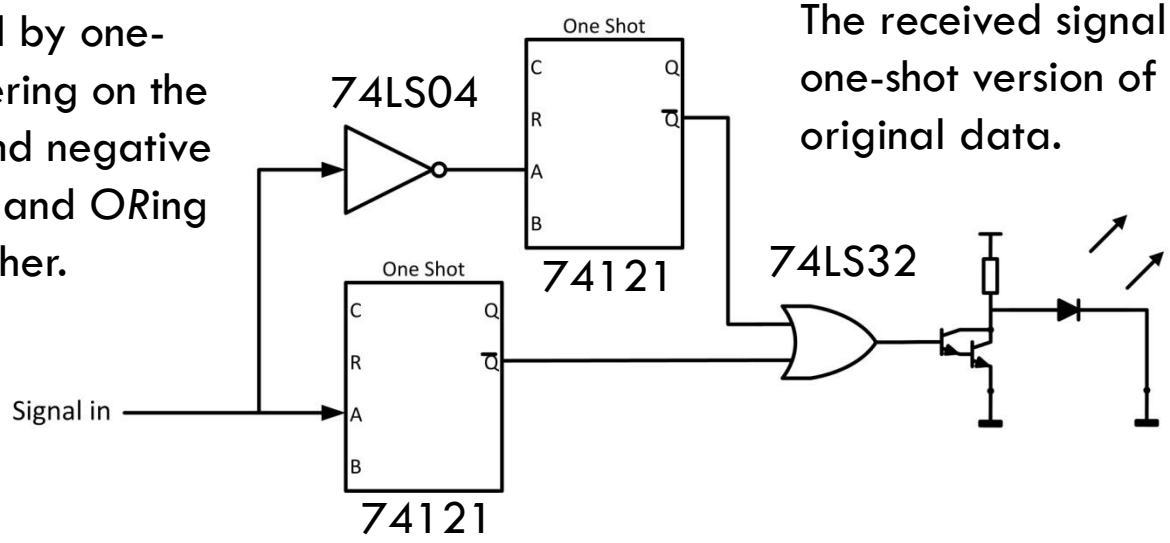
SD Card Pins

bot-thoughts.com

PPM Modulation and Demodulation

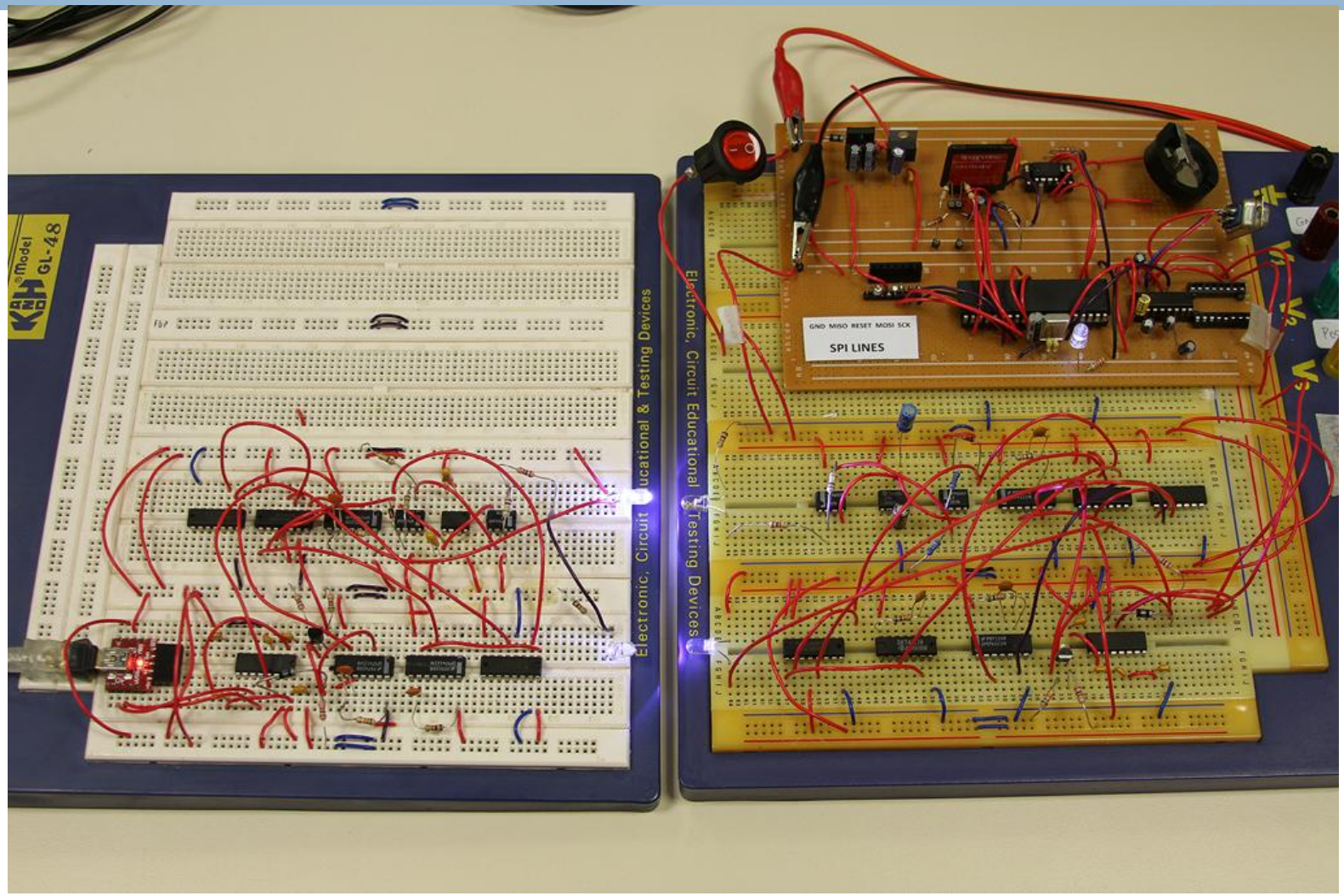


The data signal is modulated by one-shot triggering on the positive and negative transitions and ORing both together.



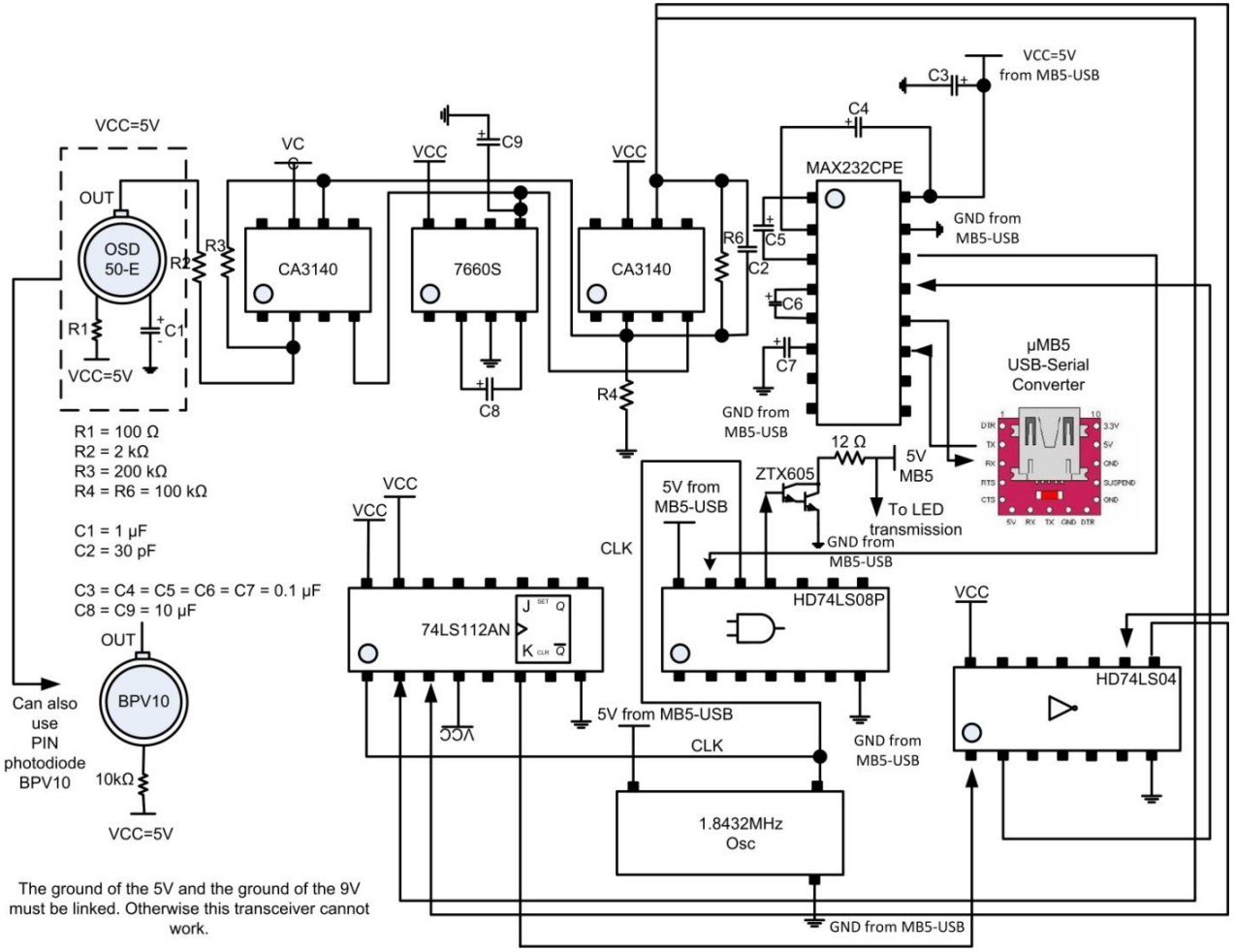
The received signal is demodulated by a one-shot version of itself to recover the original data.

PPM Transceiver



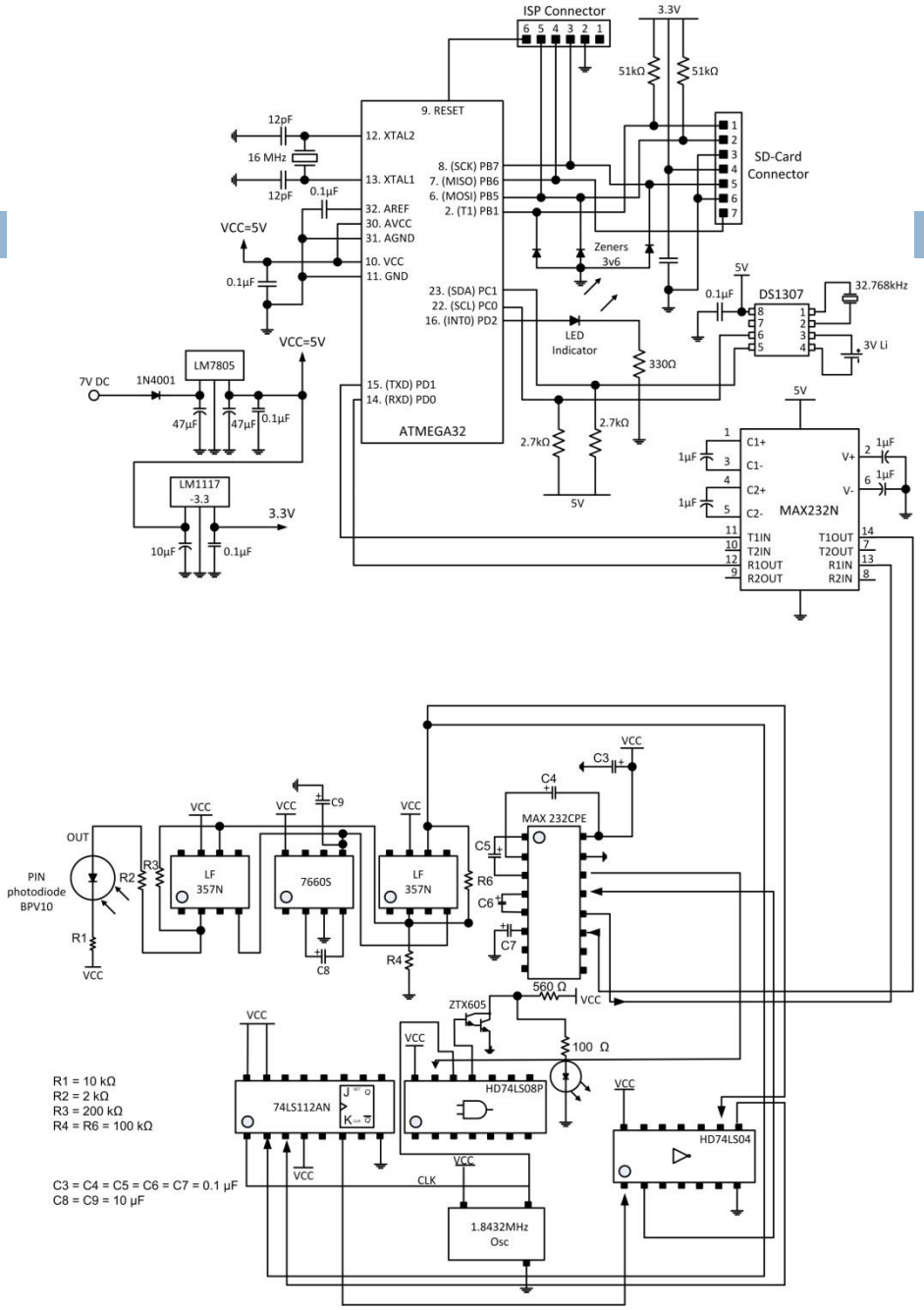
PWM Circuit

PC-side

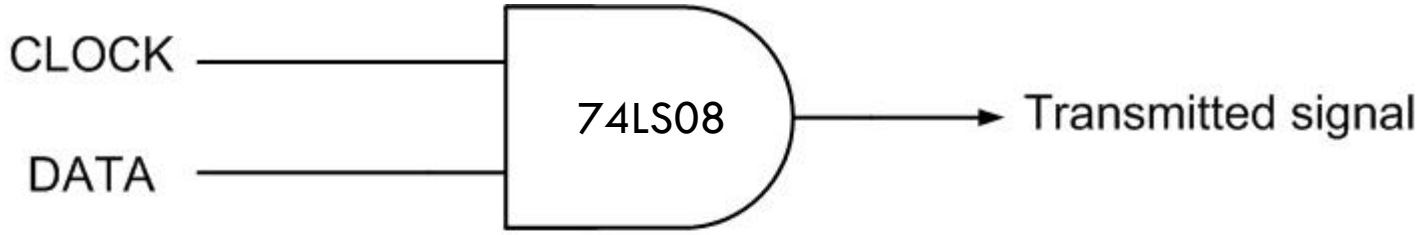


PWM Circuit

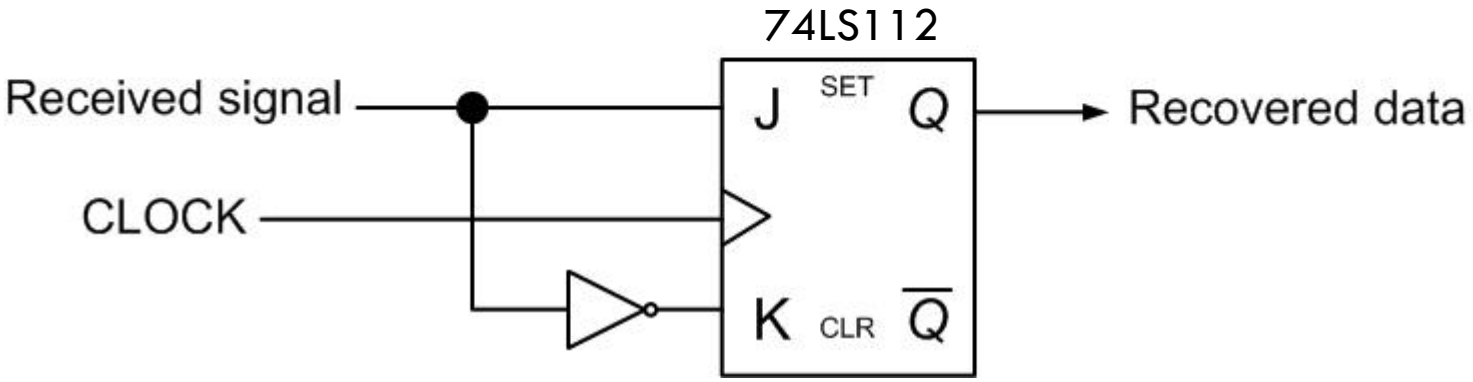
SD-card side



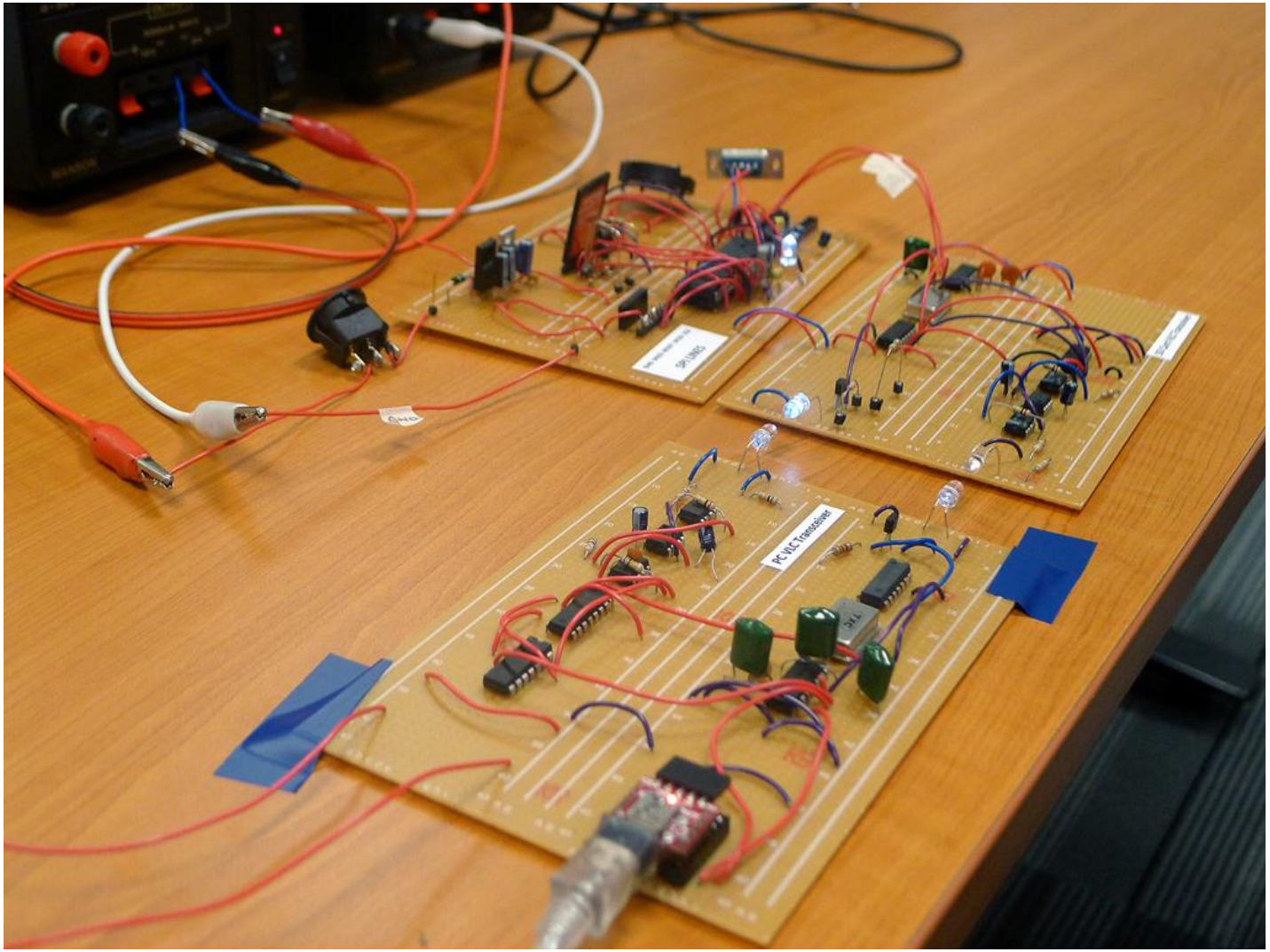
PWM Modulation and Demodulation



The clock and data are multiplexed using an AND gate 74LS08 and demultiplexed by an inverted version of itself and the clock signal.



PWM Transceiver



Performance

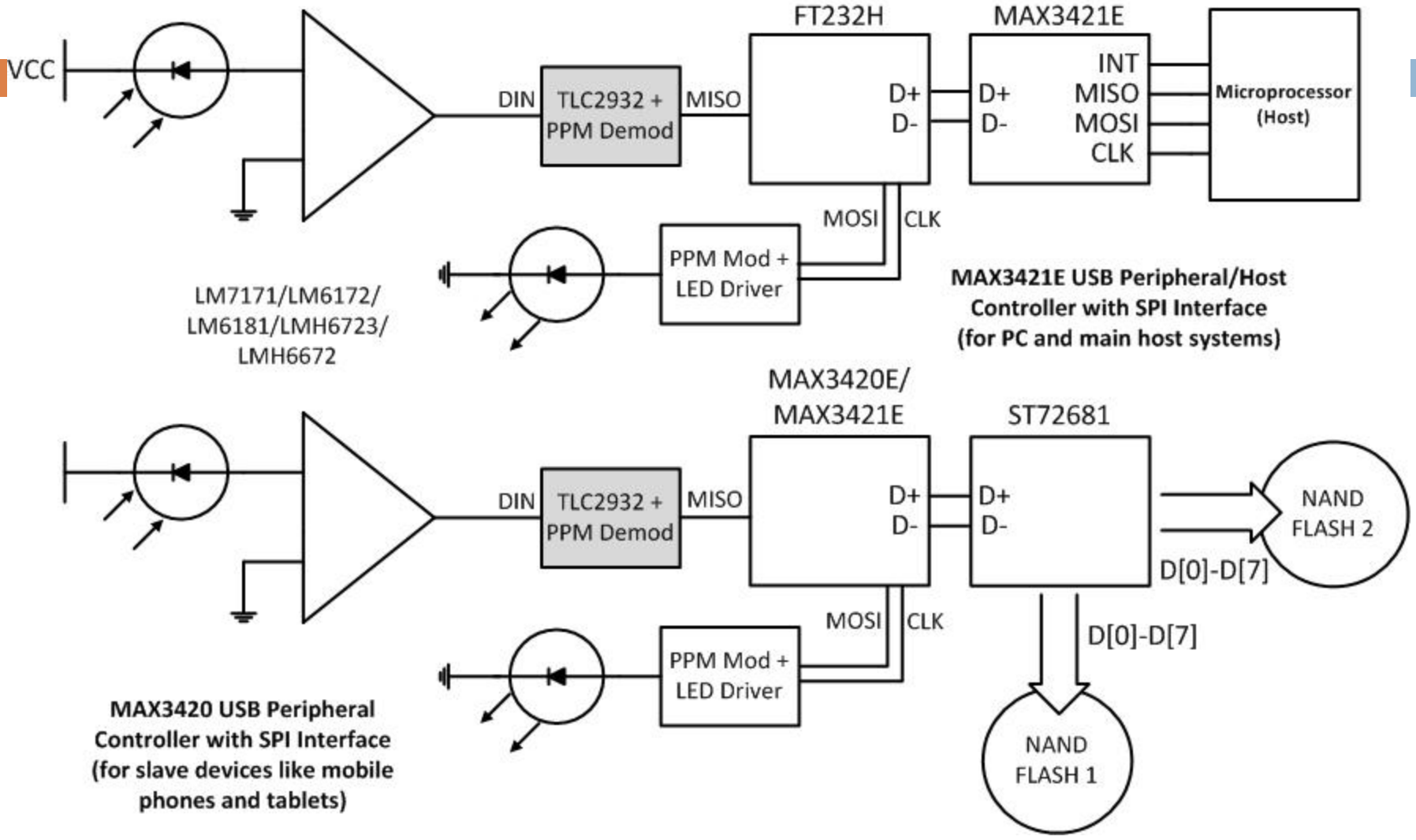
- In the Prototype 1 PPM transceiver, a supply voltage of between 6.4V and 6.6V can be used for the whole SD-card circuit (including the transceiver). A distance of about 1 cm between the LED and the photodiode is ideal for good transmission. For distances farther than 3 cm, concentrators can be used.
- In Prototype 2, the SD-card side uses a supply voltage of between 6.9V and 7.0V.
- Data rate = 19200 bps.

Conclusion and What Next?

- The prototypes are successful only in a basic form.
- To be implemented commercially,
- Speed is an issue.
- Compatibility is an issue.
- Interface is an issue.
- Cost is an issue.
- A PPM transceiver seems like a better design, since it saves power. Power consumption can be further reduced if we fabricate the entire circuit at chip level.
- A PWM transceiver is able to integrate more readily with LED lighting, since most LED drivers work on PWM.

Further Work

- 12MHz White-LED Thumbdrive for Mobile Devices

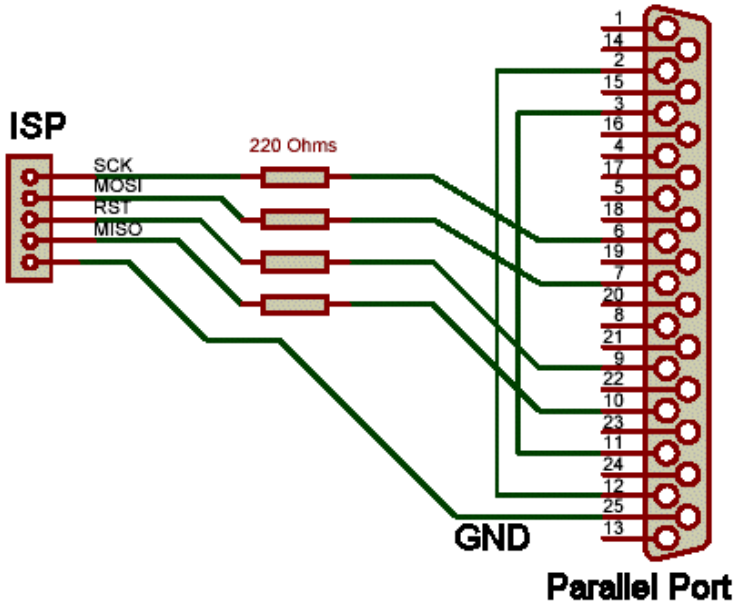

VCC
DIN
TLC2932 +
PPM Demod
MISO
FT232H
D+
D-
MAX3421E
D+
D-
INT
MISO
MOSI
CLK
Microprocessor
(Host)
MOSI
CLK
PPM Mod +
LED Driver
LM7171/LM6172/
LM6181/LMH6723/
LMH6672
MAX3421E USB Peripheral/Host
Controller with SPI Interface
(for PC and main host systems)
MAX3420E/
MAX3421E
ST72681
DIN
TLC2932 +
PPM Demod
MISO
D+
D-
D+
D-
NAND
FLASH 2
D[0]-D[7]
MOSI
CLK
PPM Mod +
LED Driver
D[0]-D[7]
NAND
FLASH 1
MAX3420 USB Peripheral
Controller with SPI Interface
(for slave devices like mobile
phones and tablets)

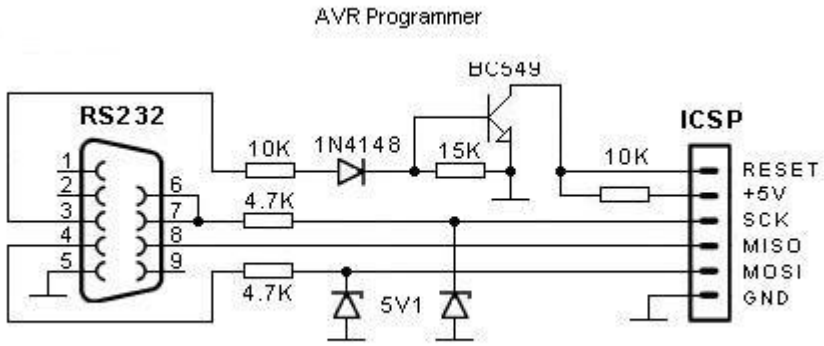
Appendix

- For any details regarding the circuits, please refer to the conference paper itself.

Programming ATMEGA32: ISP to Parallel Port Connector

- http://gopchandani.wordpress.com/2007/01/18/the-atmega32-programmer/
- http://www.avr-asm-tutorial.net/avr_en/beginner/HARDWARE.html



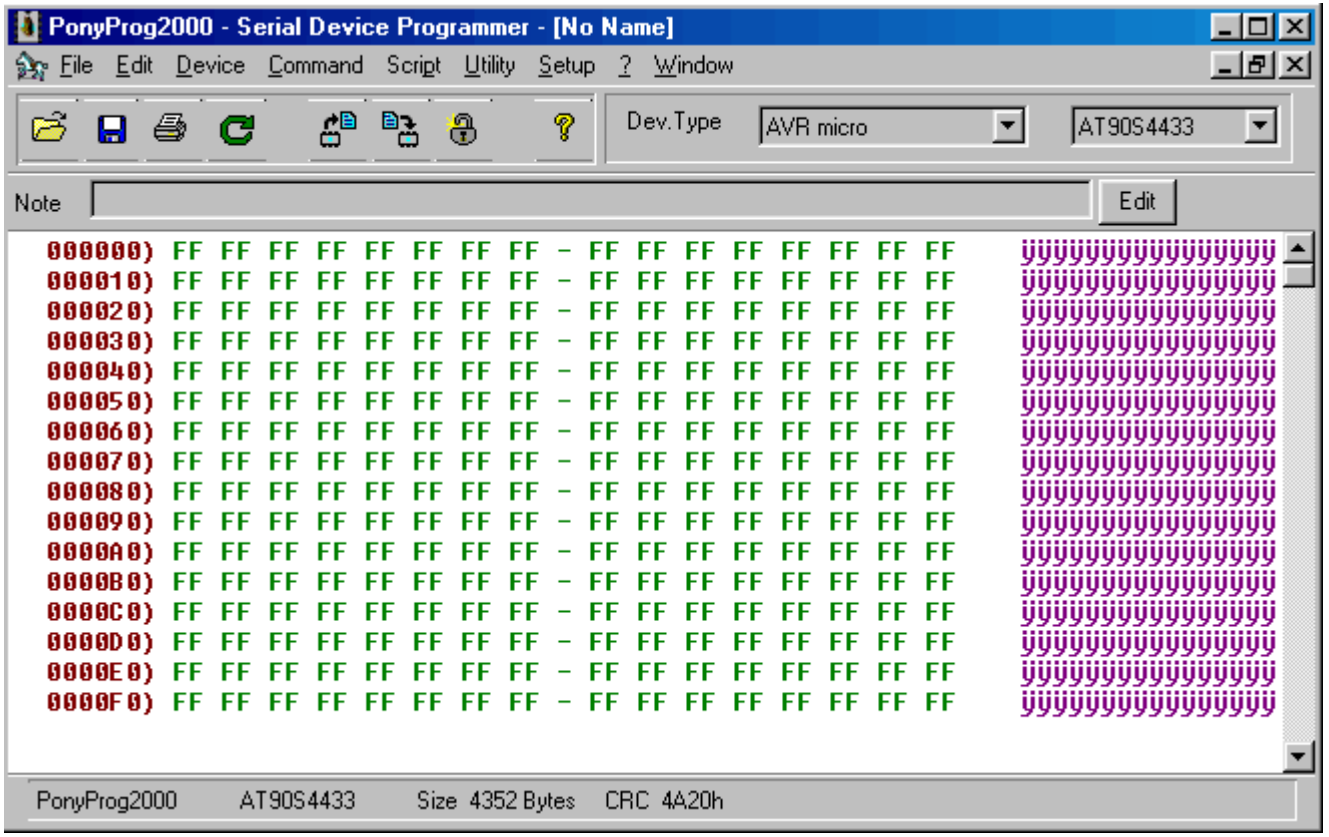


http://www.qsl.net/yo4hfu/ATMEGA_DDS.html

The one on the left is the simplest and it works! If you do not have a parallel port, you may try the one on the right.

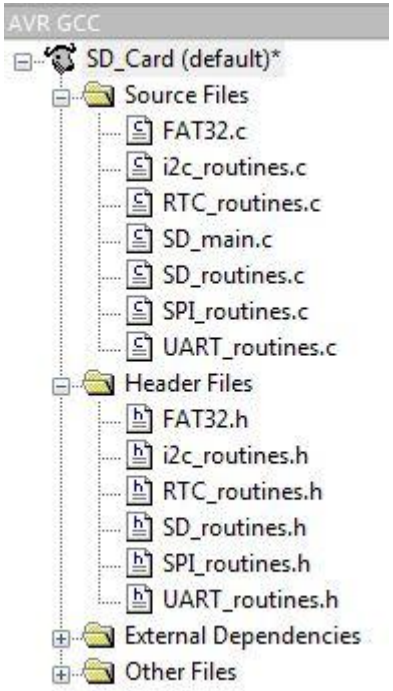
Download PonyProg Microcontroller Programmer

- http://www.lancos.com/prog.html



Download Programming Platform: AVR 6

http://www.atmel.com/microsite/atmel_studio6/default.aspx



If Studio 6 is not compatible with your PC or microcontroller, switch to Studio 5 below.

http://www.atmel.com/tools/studioarchive.aspx

References codes for FAT (must read both!)

http://www.dharmanitech.com, http://elm-chan.org/fsw/ff/00index_e.html

Useful Sites for Newbies in VLC Research

- http://extremecomputation.blogspot.com/
- http://www.instructables.com/id/Visible-Light-Transceivers/
- http://www.mathworks.com/matlabcentral/fileexchange/31792-free-space-white-led-communication-siso-and-mimo-channel-modeling