BULETINUL Universităţii Petrol – Gaze din Ploieşti	Vol. LXII No. 3B/2010	187 - 192	Seria Tehnică

Virtually USB Bus on Sine-Wave Current Supply from Infrastructure of a Smart Well

Constantin G. Popa, Alexandru D. Cojan

Universitatea Petrol-Gaze din Ploieşti, Bd. Bucureşti 39, 100680, Ploieşti,
e-mail: cgpopa@upg-ploiesti.ro, alexandru.d.cojan@gmail.com

Abstract

This paper belongs to the serial "Power Supply and Cableless Communication in a Smart Well" pondering to the feasibility of extension of a computing USB data bus with the tubing line in a smart well with a view to communicate inside out well. It presents a method of active synchronous (modulation) and demodulation of the logic states of the two USB bus differential data lines D – and D +, (on) from the two half-wave of the power supply with ultra low frequency (ULF) current injected in the well infrastructure from surface.

Key words : *Universal Serial Bus, data lines, USB bus isolator, Ultra Low Frequency, half-wave, synchronization, low power, data acquisition card, smart well.*

Universal Serial Bus (USB) – Overview

A USB system has an asymmetric design, consisting of a host, a multitude of downstream USB ports, and multiple peripheral devices connected in a tiered-star topology. Additional USB hubs may be included in the tiers, allowing branching into a tree structure with up to five tier levels.

A physical USB device may consist of several logical sub-devices that are referred to as device functions. USB device communication is based on pipes (logical channels).

A message pipe is a bi-directional pipe connected to a bi-directional endpoint that is exclusively used for control data flow. An endpoint of a pipe is addressable with tuple (device_address, endpoint_number).

When a USB device is first connected to a USB host, the USB device enumeration process is started. After reset, the USB device's information is read by the host and the device is assigned a unique 7-bit address.

The host controller directs traffic flow to devices, so no USB device can transfer any data on the bus without an explicit request from the host controller [1].

Signaling

USB signals are transmitted on a twisted-pair data cable with 90 Ω characteristic impedance, labeled D + and D −. These collectively use half-duplex differential signaling to reduce the effects of electromagnetic noise on longer lines.

Transmitted signal levels are 0.0 – 0.3 volts for low and 2.8 – 3.6 volts for high in full-bandwidth and low-bandwidth modes, and -10 – 10 mV for low and 360 – 440 mV for high in hi-bandwidth mode. In FS mode the cable wires are not terminated, but the HS mode has termination of 45 Ω to ground, or 90 Ω differential to match the data cable impedance, reducing interference due to signal reflections.

A USB connection is always between a host or hub at the 'A' connector end, and a device or hub's upstream port at the other end ('B' connector).

The host includes 15 kΩ pull-down resistors on each data line. Therefore, when no device is connected, the both data lines there are low in the so-called "single-ended zero" state (SE0), and indicates a reset or disconnected connection.

A USB device can pull one of the data lines high with a 1.5 kΩ resistor. This overpowers one of the pull-down resistors in the host and leaves the data lines in an idle state called 'J'. For USB1.x, the choice of data line indicates a device's bandwidth support ; full-bandwidth devices pull D + high, while low-bandwidth devices pull D − high.

USB data is transmitted by toggling the data lines between the J state and the opposite K state. USB encodes data using the NRZI convention; a '0' bit is transmitted by toggling the data lines from J to K or vice-versa, while a '1' bit is transmitted by leaving the data lines as-is. To ensure a minimum density of signal transitions, USB uses bit stuffing ; an extra '0' bit is inserted into the data stream after any appearance of six consecutive '1' bits. Seven consecutive '1' bits is always an error.

A USB packet begins with an 8-bit synchronization sequence '00000001'. That is, after the initial idle state J, the data lines toggle KJKJKJKK. The final '1' bit (repeated K state) marks the end of the sync pattern and the beginning of the USB frame.

A USB packet's end, called EOP (end-of-packet), is indicated by the transmitter driving 2 bit times of SE0 and 1 bit time of J state. After this, the transmitter ceases to drive the D +/ D − lines and the pull up resistors hold it in the idle state.

A USB bus is reset using a prolonged (10 to 20 milliseconds) SE0 signal.

Typical high bandwidth USB devices operate at lower data rates, often about 3 MiB/s overall. For USB 1.1, an average transfer speed of 880 KiB/s has been observed.

For isochronous devices, the bandwidth is constant, and reserved exclusively for a given device. The bus bandwidth therefore only has an effect on the number of channels that can be sent at a time, not the "speed" or latency of the transmission.

All packets are made of 8-bit bytes, transmitted least-significant bit first. A packet identifier (PID) byte is actually 4-bit PID followed by its bitwise complement. This redundancy helps detect errors. Handshake packets consist of a PID byte, and are generally sent in response to data packets. Token packets consist of a PID byte followed by 2 payload bytes : 11 bits of address and a 5-bit CRC (cyclic redundancy check). Tokens are only sent by the host, never a device. A data packet consists of the PID followed by 0–1023 bytes of data payload (at most 8 at low bandwidth), and a 16-bit CRC.

Low-bandwidth devices are supported with a special PID value, PRE [1].

Development tools

Due to the complexities of the USB protocol, USB protocol analyzers are invaluable tools to USB device developers. USB analyzers are able to capture the data on USB and display information from low-level bus states to high-level data packets and class-level information.

When developing and/or troubleshooting the USB bus, examination of hardware signals can be very important. Logic analyzers and bus analyzers are tools which collect, analyze, decode, store signals so people can view the high-speed waveforms at their leisure [1].

Isolating this bus have been met with the ADuM4160 USB isolator, a new chip-scale device, that supports direct isolation of low- and full-speed USB D + and D – lines without rewriting drivers or adding a redundant SIE (Serial Interface Engine) [2].

Ultra Low Frequency (ULF) Waves – Earth Mode Communication

The low frequency electromagnetic waves in the range ULF (ultra low frequency), (3 kHz – 300 Hz), and SLF (super low frequency), (300 Hz – 30 Hz), can penetrate the soil at depths of tens or even hundreds of meters providing a depth wireless conection [4].

A special case is the line of a producing oil well in the earth. The annular cavity formed by the well casing and the tubing could behave as a long-distance linear waveguide for the ULF electromagnetic waves thus making possible the soil-subsoil communication using the low frequency currents on the simple line consisting of tubing and casing (Figure 1).

Linear energy transfer is actually using radiated electromagnetic field power and conduction currents. The voltage of power supply generator from surface may have a rectangular or sinusoidal waveform.

Extension of a computing USB data bus with the tubing line

The bottom hole equipment doesn't have its own supply, by all means it's supplied with energy by the surface equipment using the tubing line by the data carrier wave. Thereof this carrier wave must attend during the entire monitoring of the down hole parameters. A possible value of this frequency may be 5 kHz. An unmodulated waveform will transmit data only about the source position, but it won't transmit anything else about that place, therefore, this must be differently modulated for each of the both sense of transmission ; active half-wave synchronous amplitude modulation from surface to depth and passive half-wave synchronous phase modulation from depth to surface. A low power data acquisition and control card of down hole equipment communicates with the surface computer, e.g using an USB date bus. This bus can be best intermediated by line of tubing but this thing presents several challenges :

- o The tubing line is a coarse simple half-duplex line, while the USB bus is a differential bus with two data lines, D – and D + ;
- o The SIE does not provide an external means to determine data transmission direction ;
- o The receiver and the driver of bottom hole equipment must be compatible with the pull-up and pull-down functions of passive resistors, making them match across the tubing line part ;
- o The use of ULF limits the available data rate ;
- o To transmit date over a low frequency carrier, modulation requires a synchronous;
- o Since the two voltage alternances are available on line, we can not have data on the two lines after the first appearance, the principle of causality;
- o The computer and peripherals using the USB bus must be galvanically isolated from the technological plant.

The approache to create a virtually USB bus on sine-wave current supply largely seek to sidestep the above challenges.

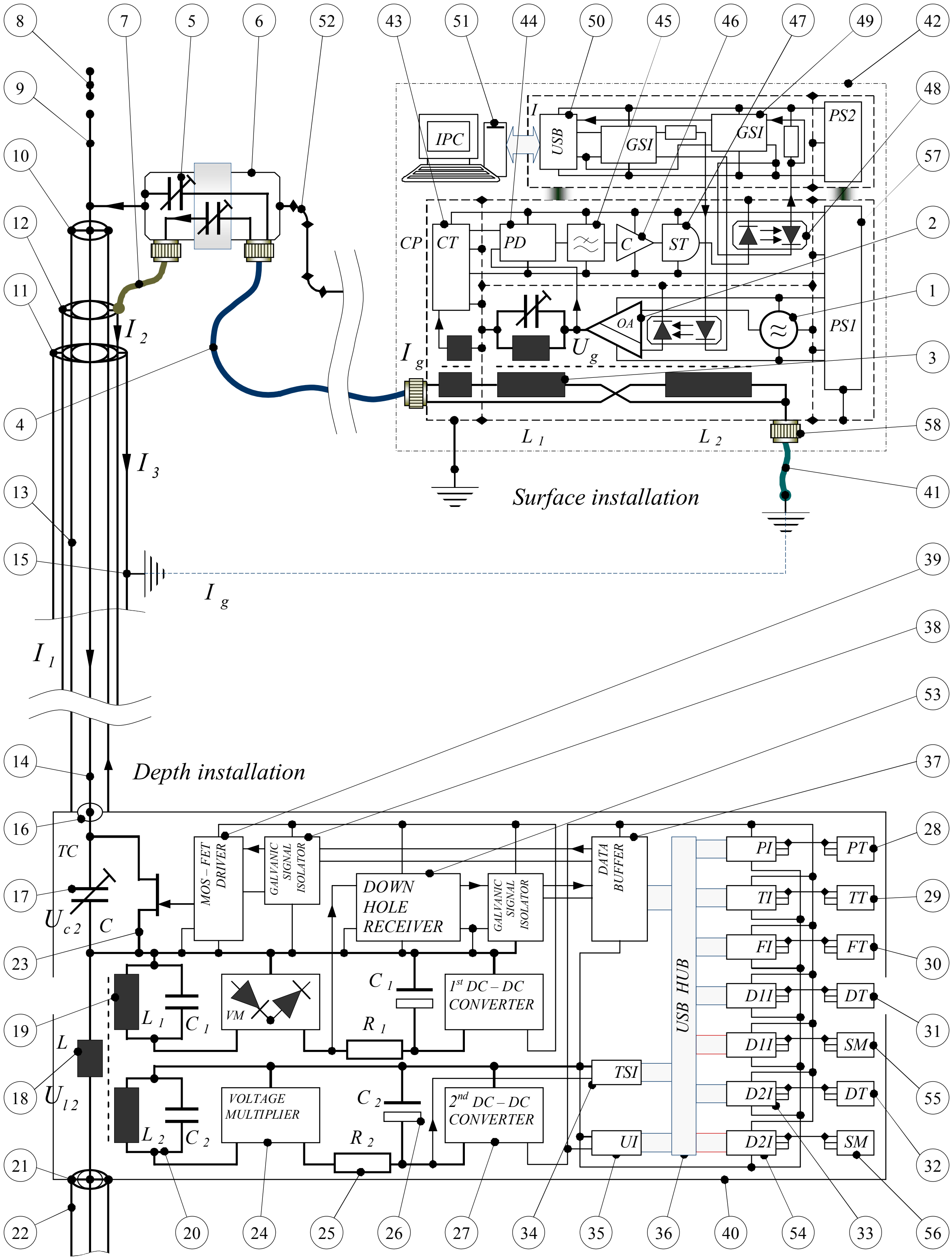

Fig. 1. The block electrical and connections diagram of oil field installation of power supply and cableless communication in a smart well

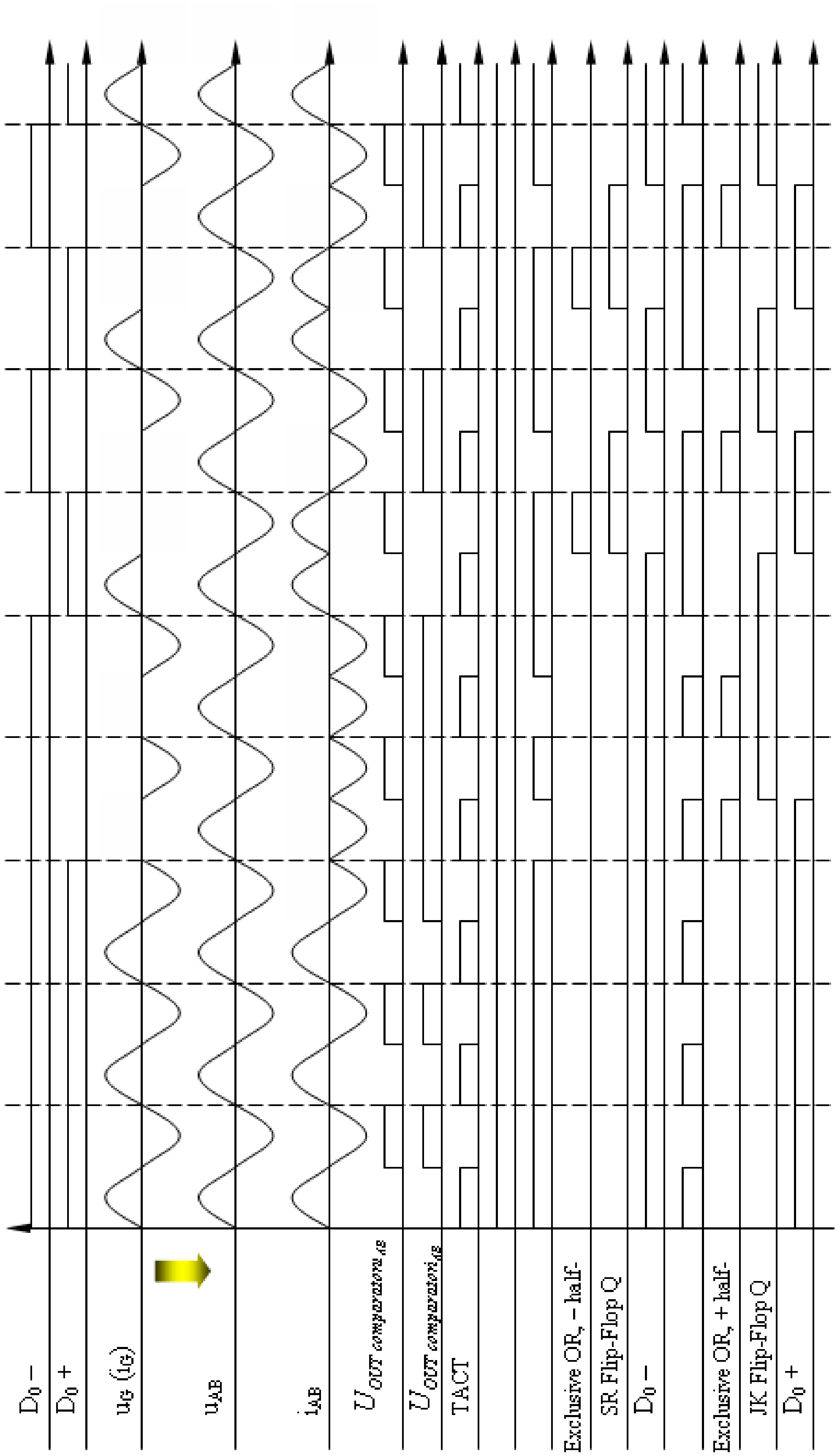

Fig. 2. Waveform of signals from down hole receiver card (the demodulator)

The logical state from the two USB data lines, D – and D +, are implemented each on the supply voltage half-waves of well infrastructure (Figure 2).

The data transmission direction is determinated by logic processing of voltage drop values found on the USB serial resistor. The pull-up and pull-down functions of passive resistors will be synthetized by the down hole / surface receiver and by the signal isolators for the low-bandwidth mode.

The data equipment and the surface power generator will be synchronized. At every query of bottom hole equipment, the surface host controller will receive data one bit delayed.

The depth demodulator detects generator voltage half-waves of zero value, by comparing the phase sense for the voltage and the current from the terminals of depth resonant circuit.

The bottom hole equipment housed in a down hole telemetry coupling contains power resonant circuits and seven blocks: low power down hole receiver, USB bus isolator, driver, multiple power supply, NI data acquisition card [3], pressure transducer, temperature transducer.

Conclusions

The paper presents an ingenuousness method of virtually USB bus on sine-wave current supply from infrastructure of a smart well. This bus can be best intermediated by line of tubing.

The new method for an actual smart well from a Romanian oil field is a feasible application. This extension of a computing USB data bus with the tubing line adds a redundancy for this line which helps recuperate the wanted signal.

The electronic components are very common and the bottom hole equipment components are in low power version or even in ultra low power version, this can be designed within standardized elements limits.

References

1. Interfacebus – *Universal Serial Bus Interface,* www.interfacebus.com
2. Cantrell, M. – *Digital isolator simplifies USB isolation,* Analog Devices, www.dataweek.co.za
3. National Instruments – *Industrial Measurement and Control*, CD, www.ni.com
4. Dolea, P. – *Transmiterea informaţiei prin unde electromagnetice de ultra joasă frecvenţă*, spacesignals.blogspot.com

Magistrală virtuală USB pe alimentarea de curent sinusoidal din infrastructura unei sonde inteligente

Rezumat

Această lucrare aparţine seriei „Alimentare şi comunicaţie fără cablu într-o sondă inteligentă" studiind posibilitatea de extensie a unei magistrale de date USB cu linia de tubing dintr-o sondă inteligentă cu scopul de a transmite informaţie din interiorul sondei la exteriorul acesteia. Ea prezintă o metodă de (modulaţie) activă şi demodulaţie, sincrone a stărilor logice ale celor două linii diferenţiale USB D – şi D +, (pe) de la cele două semiunde ale alimentării cu curent de ultra joasă frecvenţă (ULF) injectat de la suprafaţă în infrastructura sondei.