Fast, low cost fibre-optic digital signal links

1. Introduction

There are numerous applications in instrumentation systems which require the transmission of a fast logic signal through a fibre-optic cable, either for signal isolation purposes, or when such signals need to be transferred through shielded enclosures. We describe here a simple method of implementing such transfers when ultimate speed performance is not required, although the approach described here achieves a respectable performance, with a pulse width distortion of ~10 ns and is suitable for transmitting signals at rates of 20 MHz and below. This arrangement has been used to transfer fast signals to pulse modulators within the Oxford linear accelerator and to systems outside the acceprator, achieving a jitter performance of <1 ns FWHM when used with relatively short polymer fibre links (2 m and 5 m). Although polymer fibre cables are usually not advised for applications where high ionising radiation is present, we have not found this to be a problem. Glass fibres may also be used in these systems, though we have not experienced any problems with colour centre formation in polymer fibres, possibly because they are realtively porous to oxygen, which helps to eliminate colour centre darkening. Strictly speaking the term F-centre (originating from the German *Farbzentrum*) should be used. For explanation of these effects, the following references are useful:

Study of Optical Absorption in Gamma Irradiated Glass for Radiation Dosimetry Purposes. AIP Conf. Proc. 935, pp. 231-236; doi:http://dx.doi.org/10.1063/1.2795419

Radiation color center formation in silica glasses: a review of photo- and thermo-chemical aspects of the problem. 1994 A.V. Amossov A.O. Rybaltovsky, Journal of Non-Crystalline Solids, 179, 226–234, Proceedings of the First PAC RIM Meeting on Glass and Optical Materials http://dx.doi.org/10.1016/0022-3093(94)90700-5

Color Centers in Glass Optical Fiber Waveguides 1985 E. J. Friebelea and D. L. Griscoma, MRS Fall Meeting. DOI: 10.1557/PROC-61-319

Modeling of Absorption Induced by Space Radiation on Glass: A Two-Variable Function Depending on Radiation Dose and Post-Irradiation Time 2006 Fernandez-Rodriguez, M.; Alvarado, C.G.; Nunez, A.; Alvarez-Herrero, A. IEEE Transactions on Nuclear Science, **53**, 2367 – 2375. DOI 10.1109/TNS.2006.879017

In any case, the use of links operating at 650 nm is advantageous in practice, as an operational link can be easily identified a such merley by looking into the end of the fibre. Links operating at higher wavelenghts may be superior, but nowhere near as convenient as those operating at visible wavelenghts, particularly when one is faced with a bundle of unlabelled fibres during construction!

2. Fibre-optic transmit-receive devices

The system is based around industry-standard fibre-optic devices: the Avago Technologies HFBR-2506AMZ fibre-optic receiver and the HFBR-1506AMZ transmitter http://www.avagotech.com /pages/en/fiber_optics/fieldbus_sercos_interface/). These are shown in Figure 1 and use 1/4"-36 thread SMA-type connectors. The optical fibres used are available from Fibre Data (http://www.omc-uk.com/components/fibre-optics), part numbers A19A52A0 and A19A55A0 as 2 m and 5 m long terminated patch leads (also available from Farnell/One Call as stock numbers

Figure 1: The fibre-optic transmitter and receiver and the SMA-terminated glass and polymer fibres used for interconnections.

1208868 and 1208869 respectively. Alternatives, if polymer fibres are undesirable are 200/230 µm glass fibres, available from Fibre Data as part numbers A65A152A0 and A65A155A0 (Farnell/One Call stock numbers 1208907 and 1208908 respectively).

3. Fibre-optic transmit-receive circuits

An example of the electronic driver and receiver circuits are shown in Figure 2. We make use of two 74HCT540 octal inverting buffers to drive four transmitters. The outputs of 4 inverters are summed together through resistive/capacitive networks which sharpen up the LED drive signal to ensure fast transitions; approximately 35 mA LED current is used to forward bias the LED when a logic 1 is applied to the 74HCT540s.

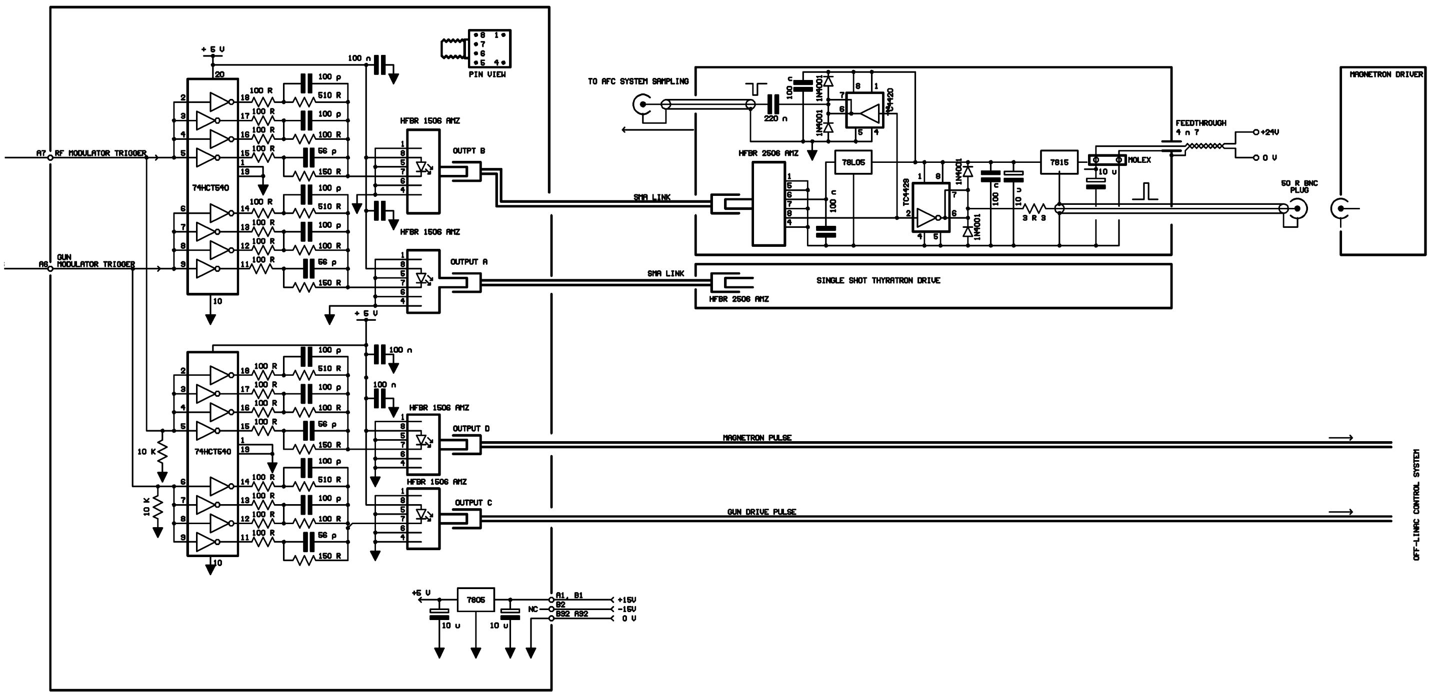

Figure 2: Example of the fibre-optic transmitter and receiver circuit, here shown providing drive pulses to the linac modulators and providing synchronous output pulses to electronics external to the linac Faraday cage.

We also show in Figure 2 an example of a high output logic level (15V) receiver. Here we make use of Microchip TC4429CPA and TC4420CPA inverting and non-inverting drivers. These are intended to be used as MOSFET gate drivers and are capable of delivering a high current into low impedance loads: in this instance input trigger circuits used in the linac's two modulators. The drivers are available from One Call as stock numbers 119-6787 and 976-2566 (as well as from other suppliers). These receivers operate close to systems which radiate large electromagnetic fields and we therefore screen them in small diecast boxes to eliminate radiated interference as much as possible. A particularly troublesome source of interference is that present on local power supply lines: here we introduce the supply through a small feed-through capacitor (Oxley DLT/4700, available as from One Call as stock number 149-151 and doubtless from other suppliers) into the receiver enclosure.

The design presented in Figure 2 is useful inside the linear accelerator. However, when taking signals to outside the linac area, logic signal amplitudes of 15 V are not so useful and a receiver design capable of driving TTL inputs which may be terminated by 50 Ω is much useful. Such an arrangement is presented in Figure 3. Here we use a low output impedance line driver, a 74F series device: 74F3037. This very useful device is not available from the 'usual' UK electronic component suppliers, though it may be obtained from RS as extended range stock number 2508330624, or more readily from Digikey (http://uk.digikey.com/) as stock number 568-1727-5-ND. This device is specified to drive loads down to 30 Ω, though we have found it useful to provide 15 Ω series output resistors to partially deal with reflections from unterminated lines. We have also found it useful to fit a link-coupled standard HC series inverter directly after the fibre-optic receiver should an inverted output be required. In general, we operate with a 'low' level at the receiver output lines to minimise power dissipation in the 74F3037 and hence minimise power supply current drain.

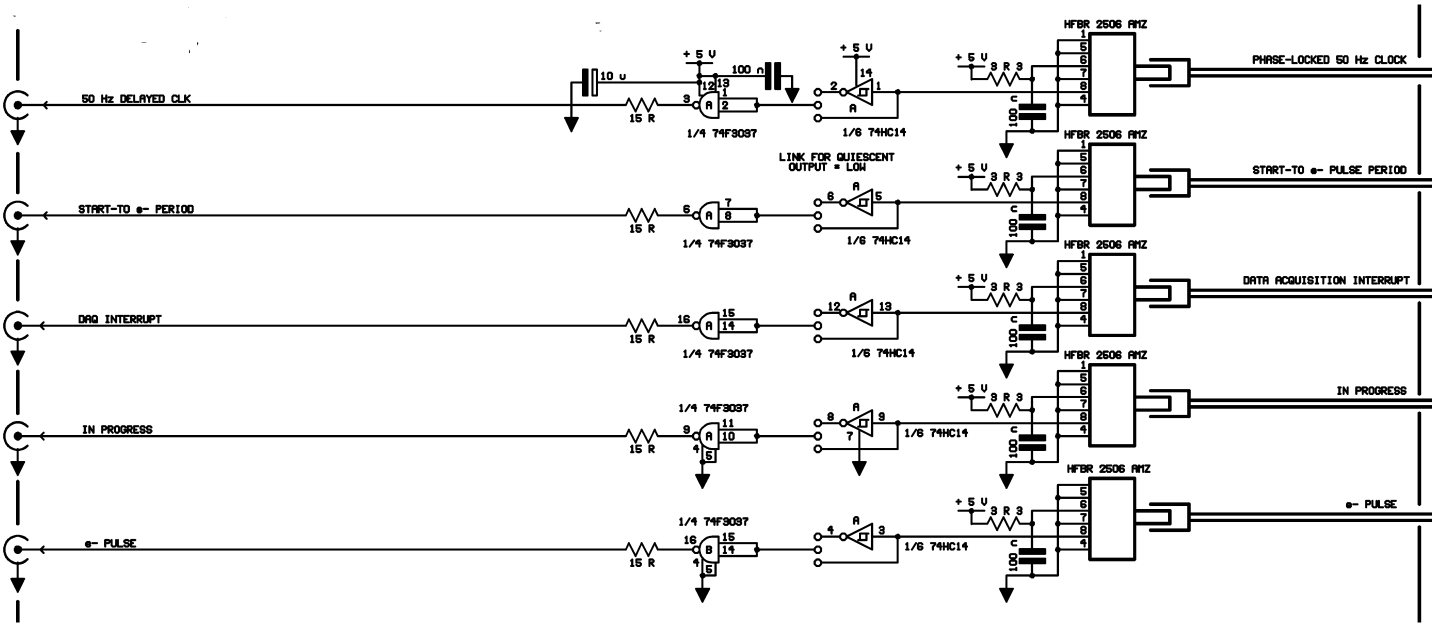

Figure 3: Example of part of a fibre-optic receiver circuit, here shown providing pulses into 50 Ω terminated lines in the experimental area outside the linac Faraday cage.

This note was prepared by B. Vojnovic and R.G. Newman in early 2012. The basic arrangement was designed by B. Vojnovic who heavily relied on R.G. Newman for putting it into practice and tracing sources of interference. His patience was a virtue!

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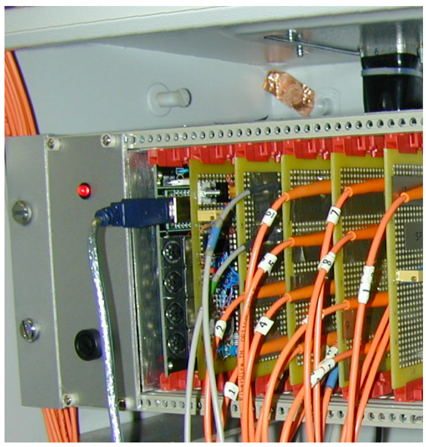

Figure 4: The linac fibre-optic transmitters / receivers handling timing data in and out of ther Faraday cage.