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DESIGN NOTE

A microwave transceiver for remote sensing of high voltages

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Abstract. A microwave transceiver is described which is designed for remote sensing of high DC and AC voltages in applications where complete electrical isolation is required between the signal and the measurement system. The isolator was specifically designed for the measurement of voltages up to 30 kV DC on a CO_2 laser where neither side of the supply was at earth potential. The isolator provided infinte isolation between the laser and the computer data acquisition system. The bandwidth of the system was sufficient to enable signals from DC to around 6 MHz to be transmitted across a laboratory (including a colour video signal). The unit is unusual in that it can transmit both true DC levels and high frequency signals with infinite electrical isolation.

1. Introduction

Remote voltage sensing of high voltage DC signals presents a number of problems relating to operator safety and the use of sensitive computer data acquisition systems when neither side of the signal is at or near ground potential. A method of providing an electrically isolated measurement of the voltage across a discharge tube for a high power CO_2 laser was required. The discharge voltage was approximately 12 kV and the open circuit voltage of the supply was approximately 28 kV. Previous attempts using a fibre-optic isolator (Evans and Harry 1988) resulted in a system with a very low signal bandwidth which did not enable high frequency transients on the DC signal to be monitored. Unlike AC signals, which can be effectively isolated using transformers, the DC case is more difficult to solve where very high voltages exist with respect to earth.

DC isolation transformers are available but are generally limited in their electrical isolation to around 5 to 10 kV and usually require one side of the signal to be at, or near, ground potential. The frequency response of these Hall effect type units is limited to around 50 kHz, which causes problems when trying to record high frequency transients superimposed on a DC level. Opto-isolators are generally not suitable for use at such high voltages or for operation with DC. Acoustic couplers, although able to provide a high degree of isolation, were not considered suitable because of the high signal bandwidth required. The problem of measuring the high DC voltage is more difficult because of a switching transient that occurs when the discharge is turned on and which can result in voltages in excess of 100 kV. The measurement system had to be compatible with a standard 1000:1 attenuating probe with an input impedance of $10^7\,\Omega$ and provide an output signal of 1 to 25 V for discharge voltages of 1 to 25 kV. To enable the high frequency transients present in the discharge, a signal bandwidth of around 5 MHz was required along with a transmitting range of 3 m.

2. Description of system

A block diagram of the system is shown in figure 1 and a schematic diagram of the transmitter circuit in figure 2. The high voltage signal from the electric discharge is first attenuated by a standard 1000:1 attenuating voltage probe and is fed into the microwave transmitter. The signal is then amplified using an OP-37 high speed operational amplifier, and a 7 V DC bias applied which is used to bias and frequency modulate the Gunn diode. A high-speed non-inverting operational amplifier with a gain of 9, buffered with a MOSFET, was used to mix the analogue signal with the DC bias. The mixed signal was clipped between 8.2 and 10.2 V rails to drive the Gunn diode. The power supply for the Gunn diode must contain very low noise since even 1 mV of noise would introduce 10 kHz deviation in the transmitted frequency. The electrical supply from a 240V high voltage isolation transformer was double-regulated to 12 V using a 7812 regulator and further regulated using a very low noise regulator. The Solfan Gunn diode assembly was operated

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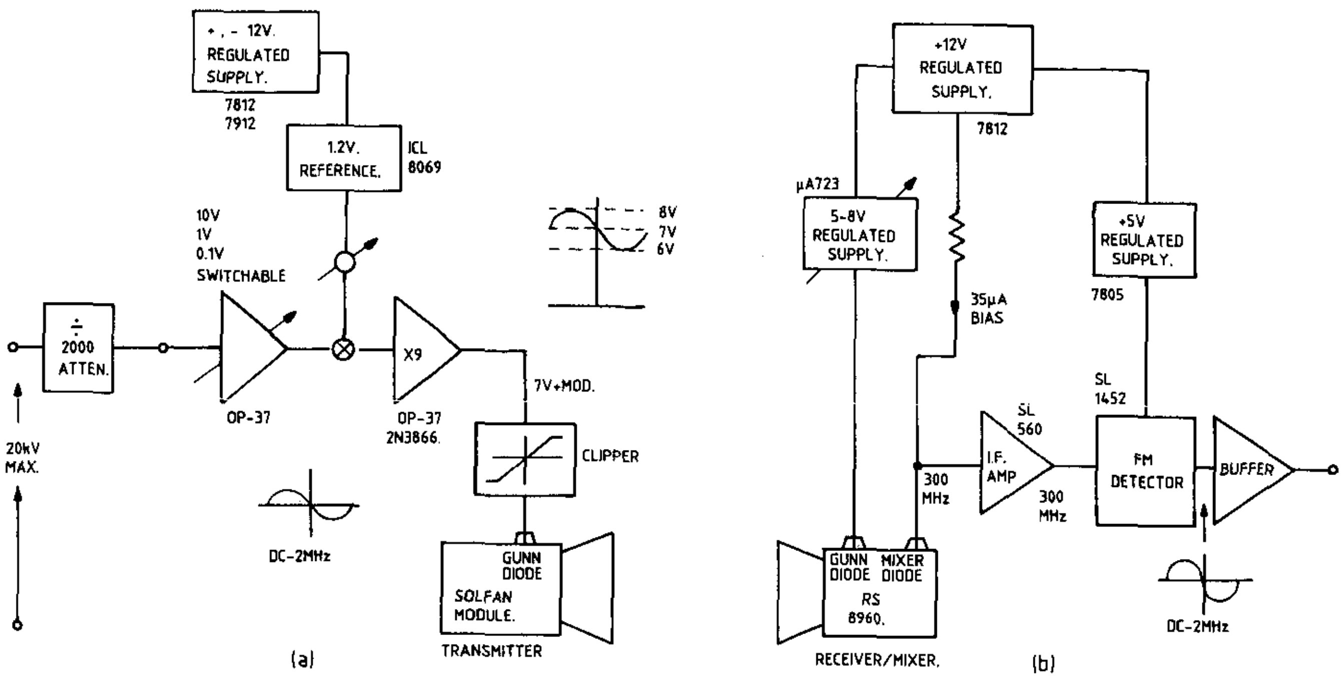

Figure 1. System block diagram: (*a*) transmitter, (*b*) receiver.

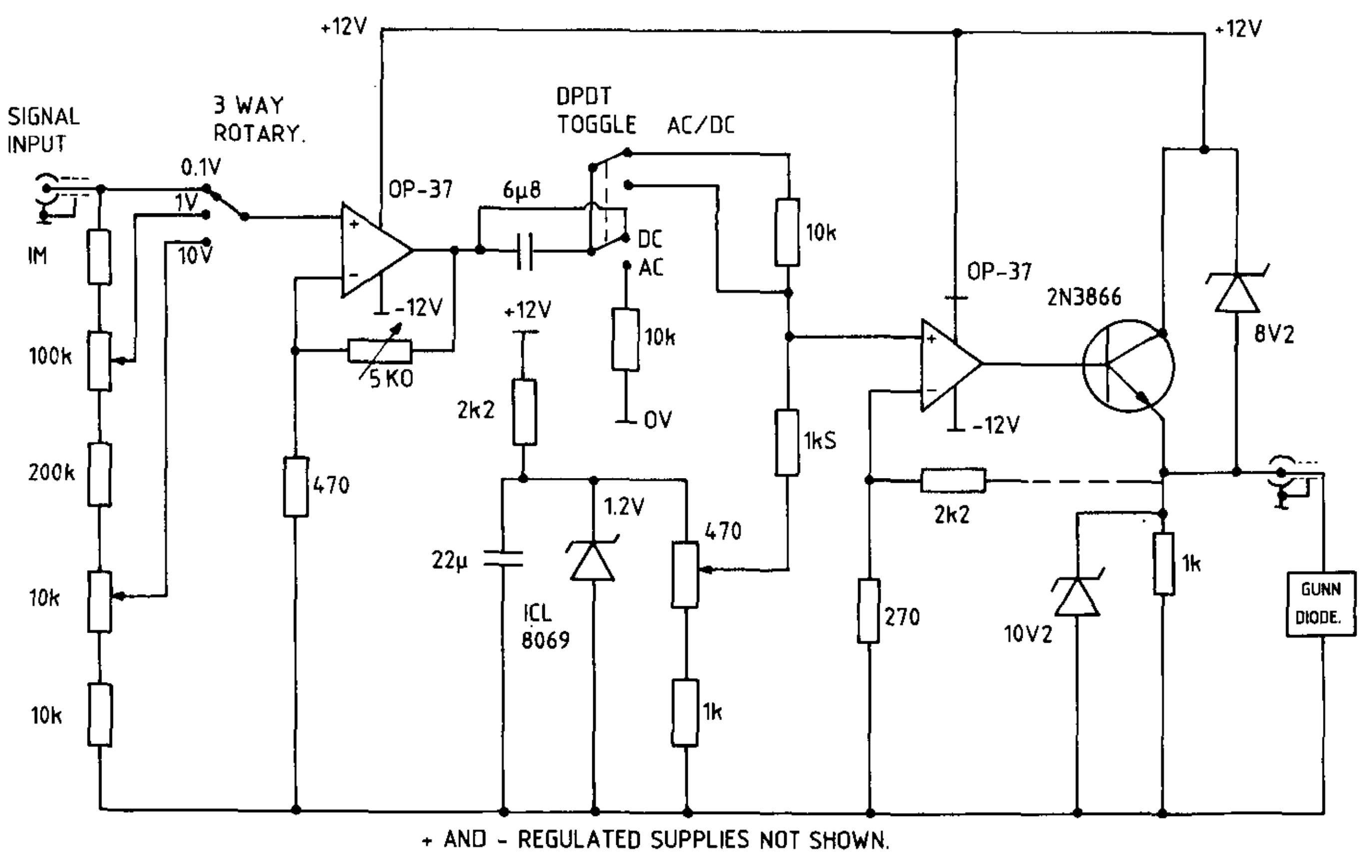

Figure 2. Transmitter circuit diagram.

at 10.39 GHz and included an integral 5 dB horn antenna.

The receiver circuit (figure 3) consists of a Gunn diode/mixer diode assembly, an intermediate frequency (IF) amplifier, a detector circuit and a final buffering amplifier. The received microwave signal is converted to a much lower frequency using a local oscillator and is then demodulated using an SL1452 wide band linear FM detector integrated circuit. The local oscillator operates at 10.69 GHz and is loosely coupled to the mixer diode

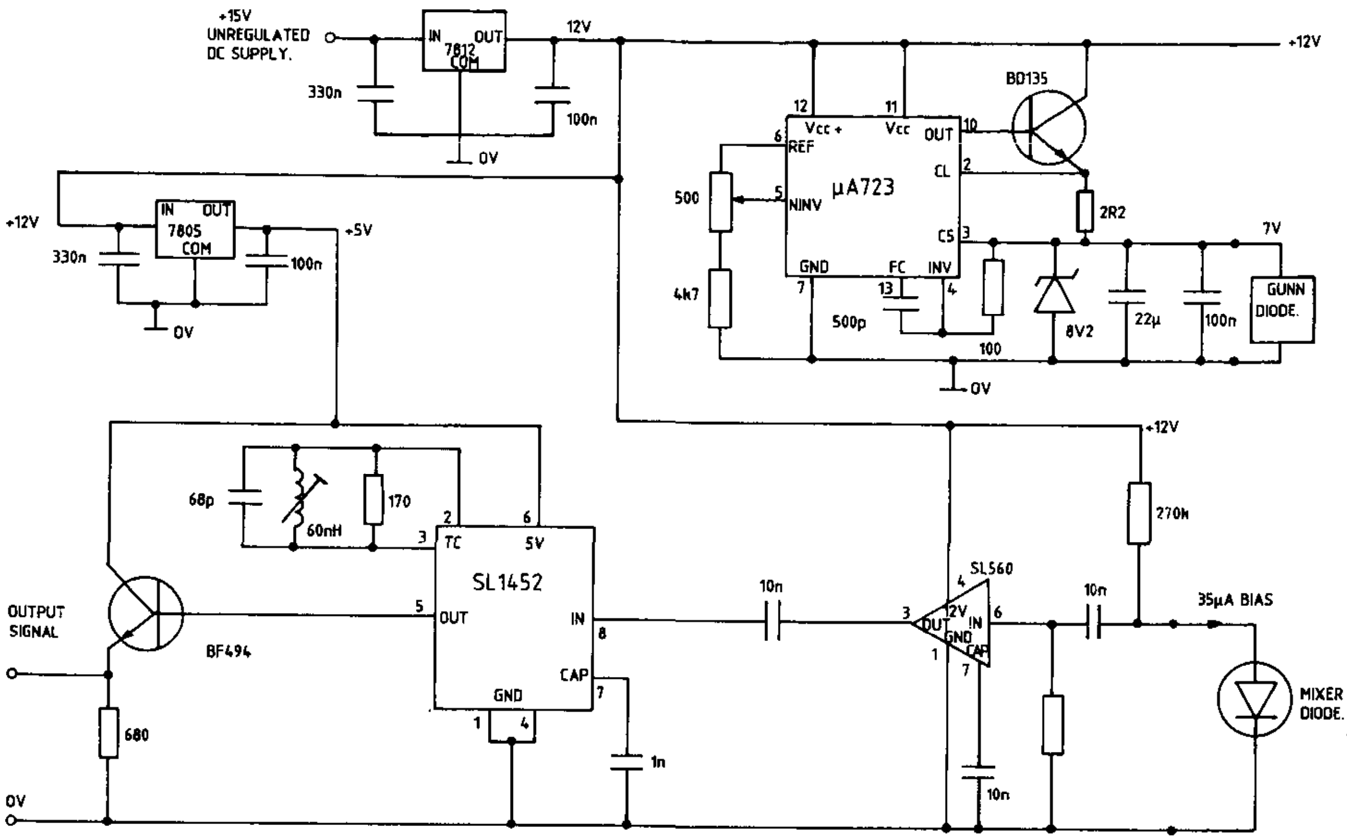

Figure 3. Receiver circuit diagram.

via a small aperture in the adjoining wall between the two diode cavities. The received microwave signal, which is centred on 10.39 GHz, is mixed with the local oscillator to provide a 300 MHz IF signal. An IF of 300 MHz was selected to allow the use of the SL560 amplifier (which has a maximum frequency response of 300 MHz) and to reduce the effects of stray capacitances and hence simplify the layout of the components. The IF signal is then amplified by 17 dB and demodulated using a wide band linear FM detector (of the type used for satellite TV applications). The frequency range of the detector was 300 to 1000 MHz. The combination of these two integrated circuits meant that mixer products above 300 MHz would not be amplified and those below 300 MHz would not be demodulated. A final stage of buffering was used to prevent loading of the detector circuit. No specific IF tuning or filtering was required due to the very high performance of the detector used and the absence of other X-band microwave signals present in the laboratory.

3. Conclusions

The microwave isolator operated over a range of 6 m, providing a very high level of voltage isolation. The system transmitted signals from DC to 6 MHz with a signal to noise ratio of around 40 dB. This system, when used in conjunction with a high voltage attenuating probe, offers the facility for safely monitoring both DC and AC signals over a range of signal amplitudes and frequencies for high voltage laboratory applications where conventional techniques do not provide adequate levels of electrical isolation for computerized data logging equipment or for personnel safety.

Reference

Evans D R and Harry J E 1988 *J. Phys. E: Sci. Instrum.* **21** 113–4