Linear Accelerator Survey Alarm for rodents

1. Introduction

Our group developed a research linear accelerator in 2008-2010, described in several application notes on our website: http://users.ox.ac.uk/~atdgroup/radiation_linac.shtml. Part of this installation includes a personnel safety interlock system described in a note entitled 'Oxford Gray Institute linac personnel safety interlock system'; this includes a survey unit that enables the start of an irradiation. This survey unit uses an audible and visual alarm that indicated that the accelerator vault is to be cleared of personnel. So far, so good, everything was developed in accordance with Health and Safety Executive Regulations[1]. A problem however arises when our accelerator was used for radiobiology work on rodents: they become very disturbed by loud, high pitched audible warning systems….! Here we describe a simple and straightforward modification to our accelerator survey unit to convert it to a system that emits audible frequencies below the hearing limit in mice[2], i.e. below 1 kHz or so.

Of course the 'obvious' way to achieve this was to construct a low frequency audio oscillator and couple it to an amplifier and thence to a loudspeaker. But we were lazy and wanted to have something simpler, convincing ourselves, quite rightly, that a complicated system prone to failure was not advisable in a safety critical system. We thus developed an arrangement that made use of existing 50 Hz 24V AC power present in our existing survey unit. This AC waveform is full-wave rectified to result in a signal of 100 Hz fundamental frequency, with harmonics that are mostly filtered out. Audi containing frequencies of 100-500 Hz is readily audible by humans. This addition to our survey unit is shown in Figure 1.

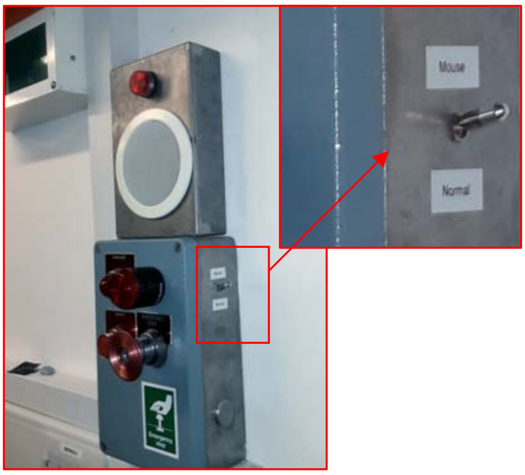

Figure 1. The completed low frequency survey indicator. Inset on the top right shows switch to select low freq. operation.

2. The circuit

The circuit used is shown in Figure 2. We use a lockable toggle switch to switch between the 'usual' pulsed sounder and flashing light (this contains a pulsing circuit and is designed to accept a 24 V AC supply) and the lower frequency mouse alarm. The full-wave-rectified 24 V AC is split into a DC path and an AC one: the DC component is 'partially wasted' in resistor R2, while the AC component is passed through RLA/2 contacts and through C1 to the loudspeaker; C1 is chosen to have a reactance comparable to that of the loudspeaker. A capacitor (C3) in shunt with the speaker forms a simple low pass filter; crude but adequate.

The 'partially wasted' DC component is next put to good use to provide a pulsing signal, generated by relay RL1. The operation relies on the fact that relay coil are associated with a larger energising voltage compared to the holding voltage: once the relay magnetic circuit is formed, its efficiency is increased and the relay stays energised until the coil voltage is significantly reduced.

When the survey button is pressed, the 24 V AC voltage charges capacitor C2 to >30 V DC and the relay coil is energised. This breaks the normally closed contacts RLA/1 and C2 discharges through R4. Eventually the relay de-energies, contacts RLA/1 close again and the cycle repeats. Really it is the same as an old-fashioned doorbell but the on-off process is slugged by the addition of R3, R4 and C2. When the relay contacts are de-energised, the loudspeaker is in circuit and vice-versa. A warning light also flashes, powered by the rectified DC though the normally open contact RLA/2.

Of course, both the flashing frequency and the mark-space ratio depend on the relay energising and holding voltages. We used a now probably obsolete relay that we had to hand, with a coil resistance of 700 Ω and nominal 24 V operating voltage. If other relay are used, some experimentation will be required to obtain a 'pleasing' mark-space ratio. All capacitors had a voltage rating of 64 V or more; nothing special, just what we had lying around….In fact everything was constructed form bits we had, including the loudspeaker (turned up as an unwanted item from an order many years ago!)

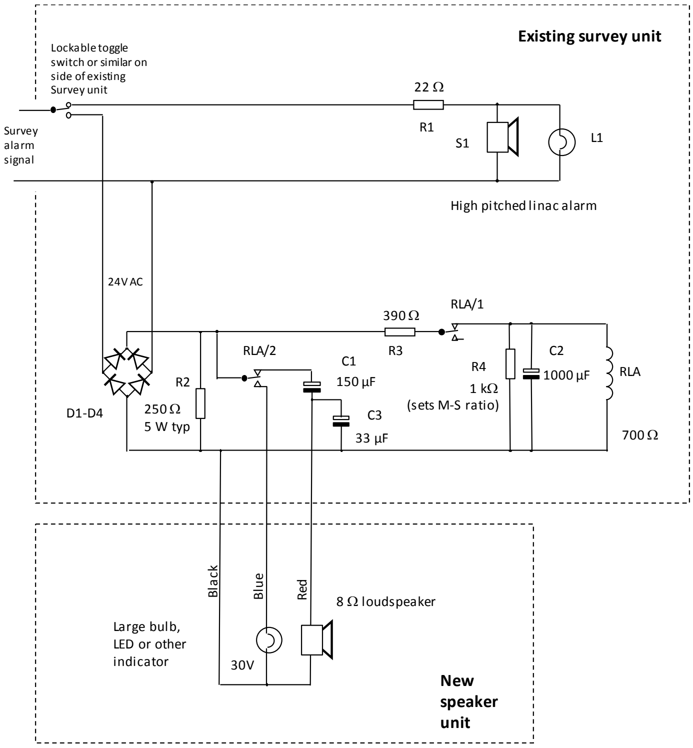

Figure 2. Circuit diagram of the low frequency survey indicator. Please see text for circuit operation details.

This arrangement was added to the unit shown in Figure 7 of our note 'Oxford Gray Institute linac personnel safety interlock system'.

It works just fine, though the speaker case shown in Figure 1 hardly follows proper loudspeaker design rules. Sure a good bass-reflex enclosure[3] would have delivered improved performance, but then the days of designing good audio systems have gone long ago!

It is noted that the 24V AC supply is almost certainly not 24V: the resistance of relatively long cables from the power source to this survey unit inevitably plays a role. Should there be significant audible 'bounce' from the survey switch, simply reverse the blue and red wires to the speaker unit; the lamp will then come on first and the sounder on the next phase, when switch bounce has settled

So in conclusion, the effectiveness of the device is excellent and the electrical efficiency is, frankly, rubbish. But it can't be beaten for simplicity!

References

1. Work with ionising radiation: HSE Ionising Radiations Regulations 1999 Approved Code of Practice and guidance1999-2012 ISBN 978 0 7176 1746 3.
2. Reynolds, R.P., Kinard, W.L., Degraff, J.J., Leverage, N. and Norton, J.N. (2010) Noise in a Laboratory Animal Facility from the Human and Mouse Perspectives. *Journal of the American Association of Laboratory Animal Science.* **49**(5): 592–597. PMID: 20858361.
3. http://hyperphysics.phy-astr.gsu.edu/hbase/Audio/basref.html.

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