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A5_6 Daisy Chaining

N. Topping, W. Butcher, N. Sisodia and J. Haywood
Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH

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Abstract
In this paper we investigated how many extension leads would be needed to be connected in succession for the final output voltage to be half of the initial input in the first cable. Assuming only losses in the wire itself and neglecting current changes and heating of the wire, we found the number of cables needed to be approximately 65.

Introduction

Strongly discouraged due to safety concerns, *'Daisy Chaining'* refers to connecting several extension leads in succession from a single power outlet. This can lead to overloading of the wires causing fuses to blow and increasing the resistance within the wires. Even more dangerous is if these wires become covered up or buried under items, causing heating of the cables. This paper investigates how many extension leads can you plug into each other before the voltage drops to half of the input voltage due to losses in the wire.

Theory

We assume the losses only occur in the wires themselves and not between connections at the main socket or the plugs of the extension leads themselves. Losses due to heating are also ignored. We assume there are no current changes in the wire and thus the voltage drop in each cable is the same. The voltage drop in a wire is given by [1]:

$$V_{drop} = \frac{I_{wire} R_{wire} 2L}{1000m/km} \tag{1}$$

where V_{drop} is the voltage drop across the wire (due to losses), I_{wire} is the current in the wire, R_{wire} is the resistance of the wire (dependent on wire material and diameter, units of Ωkm^{-1}) and L is the length of the cable. The $'2'$ accounts for the current running through the live wire and then back along the neutral wire in the cable. (Note: this equation is for a single phase AC cable, which we are assuming here for simplicity).

We determine an equation for calculating the total number of cables needed as we know the total voltage drop will be approximately equal to the final output voltage, $\frac{V_0}{2}$, divided by the number of cables, N. We also need to include the first extension lead too, thus N becomes $N-1$. Therefore, the total number of cables is given by:

$$N = \frac{V_0}{2V_{drop}} + 1 \tag{2}$$

Results

We can use an input voltage of $V_0 = 230V$, the input voltage for UK main's supply [2]. We use a standard $6m$ length extension lead with a maximum current load of $13A$ (maximum load of a UK socket [3]), and assume the wire within the cable is made purely of copper with a cross-sectional area of $1.5mm^2$, thus has resistance of $11.5\Omega km^{-1}$ [4]. We also assume that the current in the wire never increases beyond $13A$, as the majority of extension cables are surge protected and wires cannot be loaded larger than this.

Using these values and Eq. (1), the V_{drop} in each wire is found to be $1.794V$. Substituting this value and our value of V_0 into Eq. (2), the total number of extension leads required for the voltage drop to become half of the input is 65.1, or ≈ 65 cables.

Discussion

By making assumptions regarding the current in the wires in the extension leads, we find that quite a lot of cables are required before the voltage drops to half of the initial input at the main socket. In reality a lot of these assumptions cannot be made, particularly that the current would not change. Simply using $I = \frac{V}{R}$, we can see that if the voltage decreases (which, in each successive wire, the input voltage would be the previous cable's voltage minus the volt drop, thus decreasing), and resistance remains the same (material property and ignoring wire heating), then the current will decrease. Losses due to connections would also need to be considered, but this is beyond the scope of this paper.

We stated that extension leads are often surge protected, however the fuses in most have some error in the maximum current the fuse can handle. This is to allow for small surges when electronics are first plugged in and/or turned on and draw more current. However, in the case of Daisy Chaining this poses a problem, as the fuses may not blow even when there are dangerous current (and voltage) spikes, leading to electrical fires. This occurs when the spike only lasts for a small fraction of time, therefore the wire in the fuse does not get hot enough to blow (and our fuses don't blow every time we use an appliance). [5]

Conclusion

Whilst the assumptions and simplifications used in this paper allowed us to calculate the maximum number of extension leads required for the voltage in the wire to become half of the input voltage, in the future adjustments would need to be made to consider the change in current in each wire, alongside the change in voltage. This would mean that the voltage drop would change each time and therefore a new equation would need to be determined, something which could be done in future works.

References

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