# QUIZZ'AWAY


*Professor Ohsmann in e-magician's disguise during his Christmas lecture when the 'Wond`rous Light Chain' was first demonstrated.*

## Wond'rous Light Chain

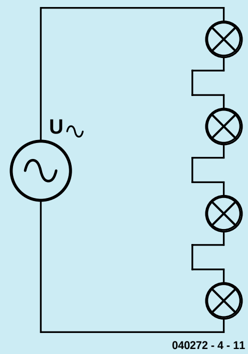
With the Festive Season upon us, it seems fitting to devote this month's Quizz'away instalment to the perennial problems associated with Christmas tree lighting. Conventionally, lamps are connected in series (**Figure 1**) and this immediately creates a problem: when one lamp fails, it breaks the series network and all other lamps will also go out. But that's not all, because in the dark you will have hard time finding the defective lamp in the first place. A solution to this problem could be to simply wire up the lamps as shown in **Figure 2**.

Let's assume each lamp is powered by way of a cable with a length *L* of 4.5 m. Twisted-pair wires from Ethernet cables are used because of their attractive colours. Close to the power supply, the cable ends are connected in series again. A photograph of the practical version is shown in **Figure 3**. Normal lamps rated at 12 V, 0.1 A are used.

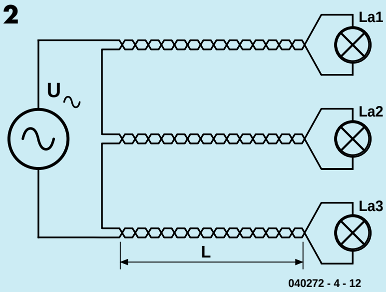
So far so good; let's connect the lot to a suitable 36 VAC power supply. This time, much to everyone's surprise, failure or removal of one lamp does not cause overall darkness — all other lamps in the Wond'rous Light Chain remain on and even light a little brighter! In this manner, the total brightness remains almost constant and the Christmas festivities are not spoilt, plus you will be able to easily spot the faulty lamp.

**Can you explain what is happening?**

1




2




3

## Quizz'away and win!

Send in the best answer to this month's Quizz'away question and win one of three **Varta Charge & Go Battery Chargers complete with 4 'Go' AA batteries** worth £50.

All answers are processed by Martin Ohsmann in co-operation with Elektor editorial staff. Results are not open to discussion or correspondence and a lucky winner is drawn in case of several correct answers.


Please send your answer to this month's Quizz'away problem, by email, fax or letter to:

**Quizz'away, Elektor Electronics,
PO Box 190,
Tunbridge Wells TN5 7WY, England.
Fax (+44) (0)1580 200616.
Email: editor@elektor-electronics.co.uk,
subject: 'quizzaway 12-04'.**

**The closing date is 22 December 2004**

(solution published in February 2005 issue). The outcome of the quiz is final. The quiz is not open to employees of Segment b.v., its business partners and/or associated publishing houses.

***As of the September 2004 issue Quizz'away is a regular feature in Elektor Electronics.***
***The problems to solve are supplied by Professor Martin Ohsmann of Aachen Technical University.***

# Solution to the October 2004 problem

## (p. 79; very high gain two-stage transistor amplifier)

The circuit diagram clearly shows that the first transistor is operated in common-emitter configuration. The second transistor is operated in common-collector mode hence does not contribute to the voltage gain.

By approximation, the voltage gain equals the product of T1's slope (in biased configuration) and its operating resistance. The slope (or transconductance) *S* is proportional to the collector resistance. For a high voltage amplification *A*, a high collector current and a high operating resistance are required. In the classical circuit, the above product is the voltage drop across the collector resistor and therefore limited by the supply voltage. Typically, the collector will be at half the supply voltage. Dividing it by the thermal voltage $U_T \approx$ 26 mV results in a maximum amplification $A$ = 6 V / 26 mV ≈ 230.

Here the circuit leaves the beaten track, the second stage acting as the operating resistance, i.e., presenting a (virtually) constant-current load to the first transistor. The crux is resistor R4 which takes an unusually small value. Because its base voltage is an almost constant 0.7 V, T2 keeps the voltage drop across R4 virtually constant. The current through R4 so determines T1's collector current at about 0.7 V / 4.7 k = 150 µA independent of the input signal. In this way, the second stage forms a very high-impedance load that, unlike a fixed resistor, will allow a relatively high collector current to flow.

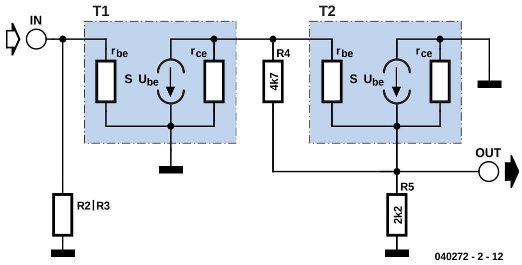



*Figure 4. Small-signal equivalent circuit.*

In order to arrive at a quantitative result, we have to calculate the internal resistance of the load. This requires looking at it in greater detail and accounting for the small-signal resistances of the transistors operating at their biasing points. The diagram in **Figure 4** shows the small-signal equivalent circuit comprising all relevant components. Resistor R4 = 4k7 is in parallel with T2's base-emitter resistance $r_{BE} \approx$ 2k5. T2's gain is just below unity (in this case, 1–1/250 = 0.996), so that the input resistance of the second stage is about 250 times R4//$r_{BE}$, which works out at about 400 k_. The internal resistance of the second stage is effectively in parallel with the output resistance $r_{CE} \approx$ 1 MΩ of the first stage. The result is that T1 sees a small-signal operating resistance of 1 MΩ//400 kΩ or about 300 kΩ. Now we can calculate the slope *S* of T1 as

$S = I_C / U_T$ = 150 µA / 26 mV
$S = 0.0058\ \Omega^{-1}$

hence

$A$ = 300 kΩ × 0.0058 ≈ 1740

which is quite close to the measured value of 1800.

**Source:**
James D. Keith,
The 'Starved-Circuit' Amplifier is revived in a transistor version,
*Electronic Design* April 2001, pp. 131.