

Video Drivers in Space-Saving  $\mu$ TQFN and Chipscale Packages

14.85mW

ISL59115/17

375mW

Competitor

Reconstruct S-Video to Composite Video using a fraction of the power consumed by competitive devices

[Ideas For Design]

## Series-Connected Transistors Use Differential Heating To Sense Airflow

W. Stephen Woodward

ED Online ID #3990

May 7, 2001

**Copyright © 2006 Penton Media, Inc., All rights reserved.**

Printing of this document is for personal use only.


[Reprints](#)

Among the methods available for airflow measurement, thermal flow meters enjoy the virtues of simplicity. They also offer simple construction, low cost, and superior sensitivity to low flow rates (less than 1000 fpm). All thermal anemometers make use of the relationship between airspeed ( $A_F$ ) and the thermal impedance ( $Z_T$ ) of a heated sensor. One practical example of such a relationship is this model of the TO-92's thermal impedance:

$$Z_T = Z_J + 1/(S_C + K_T \sqrt{A_F})$$

where:  $Z_J$  = "total immersion" junction-to-case thermal impedance = 44°C/W

$S_C$  = still-air case-to-ambient conductivity = 6.4 mW/°C

$K_T$  = King's Law thermal diffusion constant = 75  $\mu$ W/°C- $\sqrt{\text{fpm}}$

$A_F$  = airspeed in ft/min

In this model, the raw sensor output is inherently nonlinear with airspeed, a problem common to all thermal airspeed sensors. To compensate, thermal anemometer designs must include some provision for measurement linearization. The circuit in [Figure 1](#) combines ideas from two earlier IFDs ("Low-Power Thermal Airspeed Sensor," *Electronic Design*, May 25, 1998, p. 116; and "Low-Power Solid-State Airflow Detector," *Electronic Design*, Jan. 22, 2001, p. 118). In doing so, it implements a simple, linearized ( $\pm 5\%$ ), ambient-temperature-compensated thermal anemometer. A robust, power-efficient device, it draws less than 1 W of total operating power from a single regulated 5-V rail.

### Sensors



### Touch Screens



MORE

In operation, A1 maintains a constant temperature differential (about  $25^{\circ}\text{C}$ ) between Q1 and Q2, independent of changes in thermal impedance and ambient temperature. A1 achieves this by maintaining a constant ratio between the two transistors'  $V_{BE}$  voltages. It can do so by controlling the collector currents of the series-connected devices, and thereby their power dissipation.

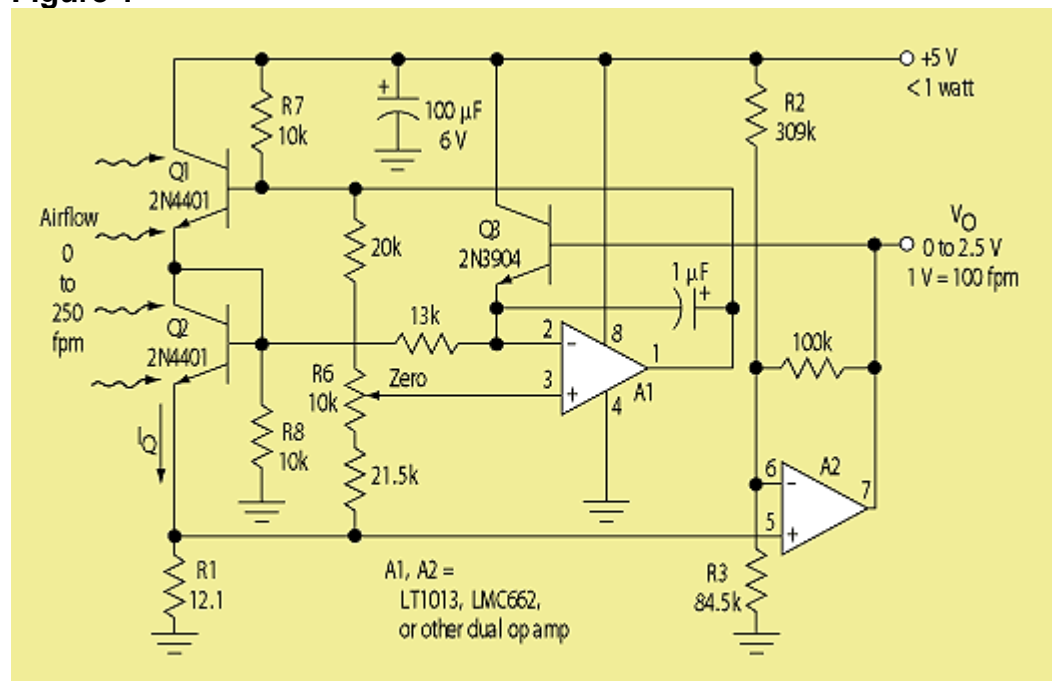
Since both transistors pass the same current ( $I_Q$ ), their relative power dissipations are determined solely by their respective  $V_{CE}$  voltages.  $V_{Q1} > V_{Q2}$  for all valid operating modes (Q3 sees to this). So for any given  $I_Q$ , Q1 will always dissipate more power and more heat, meaning it will run hotter than diode-connected Q2. Consequently, as airflow increases and thermal impedance decreases, A1 can hold any chosen Q1/Q2 temperature differential by increasing  $I_Q$ . The resulting airflow-dependent  $I_Q$  is sensed by R1, then offset and boosted by A2. In turn, it becomes the 0- to 2.5-V anemometer output signal  $V_O$ , scaled for  $10\text{ mV} = 1\text{ fpm} = 0\text{ to }250\text{ fpm}$  ( $\sim 2.5\text{ kts}$ ).

Meanwhile, Q3 acts with A2 to limit the maximum voltage across R1 to about 2 V. This is done to avoid the risk of latch-up, which would occur if A1's output were allowed to rise too near the 5-V rail. In that event,  $V_{Q1}$  would approach  $V_{Q2}$ . As a result, it would be impossible to achieve the programmed temperature differential and Q1/Q2  $V_{BE}$  ratio, no matter how high  $I_Q$  might rise. Similarly, R7 and R8 prevent latch-up when the circuit is first powered up.

But what about measurement linearization? As illustrated in Figure 2, the inherent quadratic relationship that exists between  $I_Q$  and Q1/Q2's power dissipation does a fair job of canceling nonlinearity. It erases all but  $\pm 5\%$  FSR linearity error over the entire range of on-scale airspeeds. Also, anemometer calibration is quick and straightforward. The transistor sensor pair is simply placed in slowly moving air (almost, but not quite stagnant;  $A_F = 5\text{ to }7\text{ fpm}$  is ideal). R6 is then adjusted for  $V_O = 0$ .

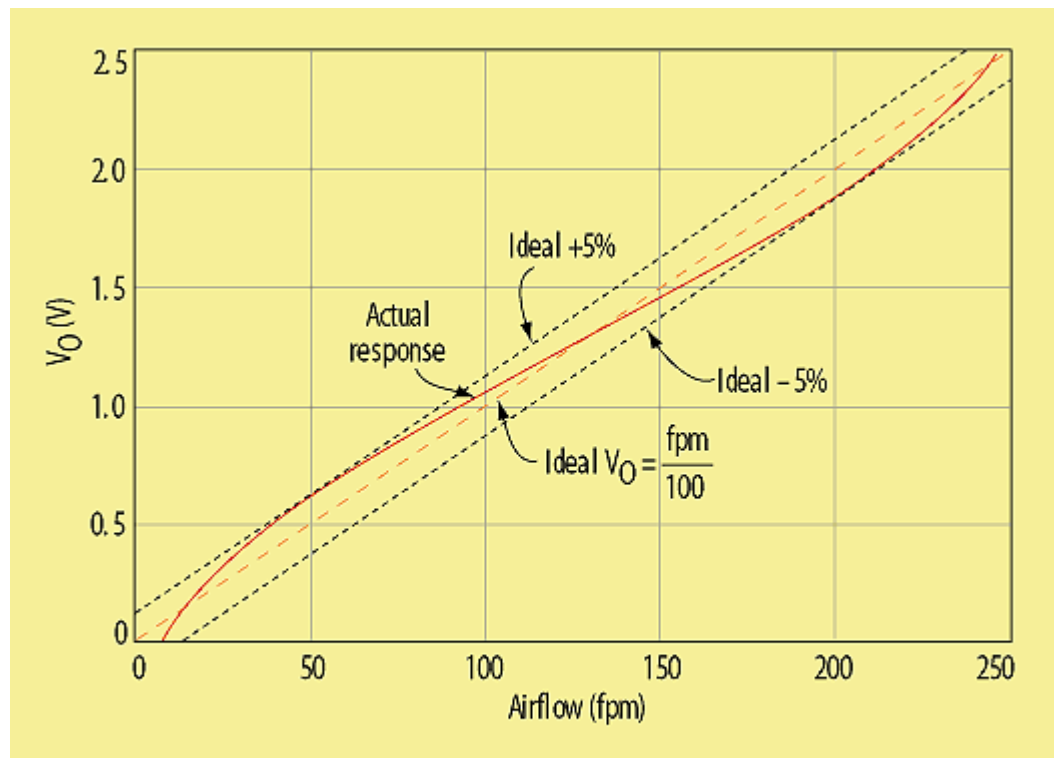
The "tranemometer" is illustrated with circuit constants that scale its output for  $V_O = 0.01\text{ V/fpm} = 1\text{ V/kt}$ . Yet virtually any range of airflow rates can be accommodated with appropriate choices for R1, R2, and R3.

**Figure 1**



1. The circuit combines ideas from two earlier IFDs to implement a simple, linearized thermal anemometer. An ambient-temperature-compensated device, it is robust and power-efficient.

**Figure 2**



2. The quadratic relationship between IQ and Q1/Q2's power dissipation does a fair job of canceling nonlinearity, erasing all but  $\pm 5\%$  FSR linearity error over the range of on-scale airspeeds.

## Marketplace

### Join the EE Social Revolution with PlanetEE.com

Looking for the latest and greatest EE resources from around the Web? Join PlanetEE and experience social bookmarking with fellow engineers from North America, Asia and Europe.

### Download Free Electronic Design Whitepapers to your PC

Electronic Design's whitepaper section brings you free PDFs to save and use as a reference for your projects. Register and start downloading today.

### Engineering TV: Videos for Electronic and Machine Design Engineers

Designed for Engineers, Engineering TV brings the world of electronics alive with twice-weekly video from tradeshows including Embedded, DAC, CES and more. You can watch interviews with design engineers, product managers and industry captains.

## Sponsored Links

### Amplifiers Circuits

10 top Amplifiers Circuit  
Amplifiers Circuits sites  
[ItsInThere.com](http://ItsInThere.com)

### RF Amps - 0.01 to 45 C

Low Noise, Broadband,  
Commercial, Military, Sp  
[www.lucix.com](http://www.lucix.com)

### Amplifiers

Find, compare & buy Cc  
1000's of Stores  
[www.Shopping.com](http://www.Shopping.com)

### UV Sensors

Full line of sensors Also  
more  
[www.solarlight.com](http://www.solarlight.com)

### Microwave Amplifiers

Call now, in stock high c  
equipment worldwide  
[www.TestEquipmentConn](http://www.TestEquipmentConn)

Electronic Design Europe ■ ■ ■ Electronic Design China ■ ■ ■ EEPN ■ ■ ■ Microwaves & RF ■ ■ ■ Schematics ■ ■ ■  
Find Power Products ■ ■ ■ Military Electronics ■ ■ ■ Featured Vendors ■ ■ ■ EE Events ■ ■ ■ Free Design Resources

[Planet EE Network](#) | [Contact Us](#) | [Editorial Calendar](#) | [Media Kit](#) | [Submit Articles](#) | [Headlines](#) | [Site Feedback](#) |  
[Subscribe](#)

[Advanced Search](#) | [Help](#)

Copyright © 2007 Penton Media, Inc., All rights reserved. [Privacy](#)

