BURR-BROWN®

4213

# MULTIPLIER-DIVIDER

## FEATURES

- LOW COST
- DIFFERENTIAL INPUT
- ACCURACY 100% TESTED AND GUARANTEED
- LOW NOISE
  120$\mu$V, rms, 10Hz to 10kHz
- SELF-CONTAINED
  No additional amplifiers
- SMALL SIZE
  Hermetic TO-100 package
- WIDE TEMPERATURE OPERATION

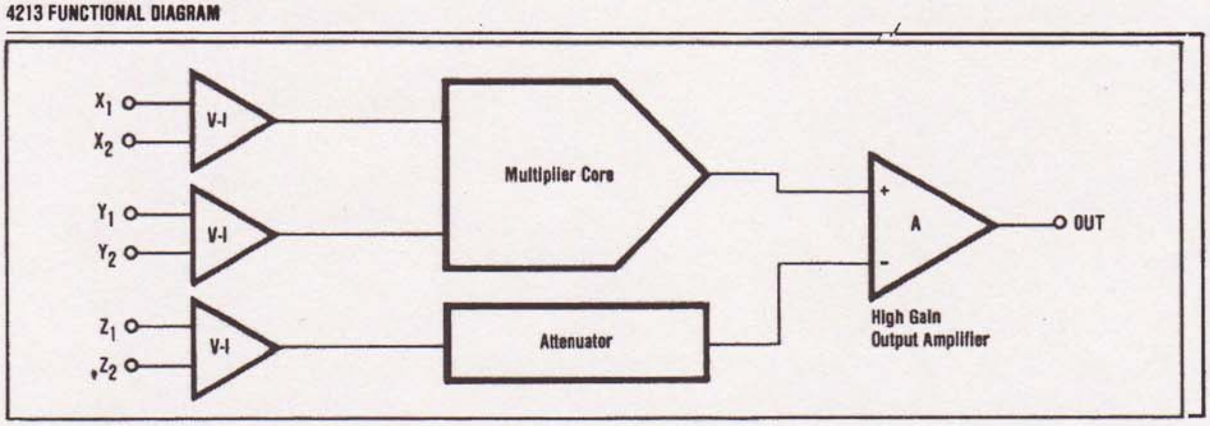
## APPLICATIONS

- MULTIPLICATION
- DIVISION
- SQUARING
- SQUARE ROOT
- LINEARIZATION
- POWER COMPUTATION
- ANALOG SIGNAL PROCESSING
- ALGEBRAIC COMPUTATION
- TRUE RMS-TO-DC CONVERSION

## DESCRIPTION

The 4213 multiplier-divider is a low cost precision device designed for general purpose application. In addition to four-quadrant multiplication, it also performs analog square root and division without the bother of external amplifiers. The 4213 is laser-trimmed to guarantee its rated accuracy with no external components. The internal zener regulated references make the 4213 much less sensitive to supply variation than earlier IC multipliers. Hermetic TO-100 package, wide operating temperature range, low output noise, and low cost are some of the desirable features of this versatile device.

4213 FUNCTIONAL DIAGRAM

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SBOS175
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# SPECIFICATIONS

## ELECTRICAL

Specifications at $T_A$ = +25°C and ±$V_{CC}$ = 15VDC unless otherwise noted.

| MODEL | | 4213AM | | | 4213BM | | | 4213SM | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **PARAMETER** | **CONDITIONS** | **MIN** | **TYP** | **MAX** | **MIN** | **TYP** | **MAX** | **MIN** | **TYP** | **MAX** | **UNITS** |
| **MULTIPLIER PERFORMANCE** | | | | | | | | | | | |
| Transfer Function | | | $\frac{(X_1 - X_2)(Y_1 - Y_2)}{10} + Z_2$ | | | • | | | • | | |
| Total Error | $-10V \leq X, Y \leq 10V$ | | | | | | | | | | |
| Initial | $T_A = +25°C$ | | | ±1.0 | | | ±0.5 | | | ±0.5 | % FSR |
| vs Temperature | $-25°C \leq T_A \leq +85°C$ | | ±0.008 | ±0.02 | | • | • | | -- | -- | % FSR/°C |
| vs Temperature | $-55°C \leq T_A \leq +125°C$ | | -- | -- | | -- | -- | | ±0.025 | ±0.05 | % FSR/°C |
| vs Supply | | | ±0.05 | | | • | | | • | | % FSR/% |
| Individual Errors | | | | | | | | | | | |
| Output Offset | | | | | | | | | | | |
| Initial | $T_A = +25°C$ | | ±10 | ±50 | | ±7 | ±25 | | ±7 | ±25 | mV |
| vs Temperature | $-25°C \leq T_A \leq +85°C$ | | ±0.7 | ±2.0 | | ±0.3 | ±0.7 | | -- | -- | mV/°C |
| vs Temperature | $-55°C \leq T_A \leq +125°C$ | | -- | -- | | -- | -- | | ±0.3 | ±0.7 | mV/°C |
| vs Supply | | | ±0.25 | | | • | | | • | | mV/% |
| Scale Factor Error | | | | | | | | | | | |
| Initial | $T_A = +25°C$ | | ±0.12 | | | • | | | • | | % FSR |
| vs Temperature | $-25°C \leq T_A \leq +85°C$ | | ±0.008 | | | • | | | -- | | % FSR/°C |
| vs Temperature | $-55°C \leq T_A \leq +125°C$ | | -- | | | -- | | | ±0.008 | | % FSR/°C |
| vs Supply( | | | ±0.05 | | | • | | | • | | % FSR/% |
| Nonlinearity | | | | | | | | | | | |
| X Input | X = 20V, p-p; Y = ±10VDC | | ±0.08 | | | • | | | • | | % FSR |
| Y Input | Y = 20V, p-p; X = ±10VDC | | ±0.01 | | | • | | | • | | % FSR |
| Feedthrough | f = 50Hz | | | | | | | | | | |
| X Input | X = 20V, p-p; Y = 0 | | 30 | | | • | | | • | | mV, p-p |
| Y Input | Y = 20V, p-p; X = 0 | | 6 | | | • | | | • | | mV, p-p |
| vs Temperature | $-25°C \leq T_A \leq +85°C$ | | 0.1 | | | • | | | -- | | mV, p-p/°C |
| vs Temperature | $-55°C \leq T_A \leq +125°C$ | | -- | | | -- | | | 0.1 | | mV, p-p/°C |
| vs Supply | | | 0.15 | | | • | | | • | | mV, p-p/% |
| **DIVIDER PERFORMANCE** | | | | | | | | | | | |
| Transfer Function | $X_1 > X_2$ | | $\frac{10(Z_1 - Z_2)}{(X_1 - X_2)} + Y_2$ | | | • | | | • | | |
| Total Error (with external adjustments) | X = -10V<br>$-10V \leq Z \leq +10V$ | | ±0.75 | | | ±0.35 | | | ±0.35 | | % FSR |
| | X = -1V<br>$-1V \leq Z \leq +1V$ | | ±2.0 | | | ±1.0 | | | ±1.0 | | % FSR |
| | $-10V \leq X \leq -0.2V$<br>$-10V \leq Z \leq +10V$ | | ±5.0 | | | ±1.0 | | | ±1.0 | | % FSR |
| **SQUARER PERFORMANCE** | | | | | | | | | | | |
| Transfer Function | | | $\frac{(X_1 - X_2)^2}{10} + Z_2$ | | | • | | | • | | |
| Total Error | $-10V \leq X \leq +10V$ | | ±0.6 | | | ±0.3 | | | ±0.3 | | % FSR |
| **SQUARE-ROOTER PERFORMANCE** | | | | | | | | | | | |
| Transfer Function | $Z_1 < Z_2$ | | $+\sqrt{10(Z_2 - Z_1)}$ | | | • | | | • | | |
| Total Error | $1V \leq Z \leq 10V$ | | ±1 | | | ±0.5 | | | ±0.5 | | % FSR |
| **AC PERFORMANCE** | | | | | | | | | | | |
| Small-Signal Bandwidth | ±3dB | | 550 | | | • | | | • | | kHz |
| 1% Amplitude Error | Small Signal | | 70 | | | • | | | • | | kHz |
| 1% (0.57°) Vector Error | Small Signal | | 5 | | | • | | | • | | kHz |
| Full Power Bandwidth | $\|V_o\| = 10V, R_L = 2k\Omega$ | | 320 | | | • | | | • | | kHz |
| Slew Rate | $\|V_o\| = 10V, R_L = 2k\Omega$ | | 20 | | | • | | | • | | V/µsec |
| Settling Time | $\epsilon = \pm1\%, \Delta V_o = 20V$ | | 2 | | | • | | | • | | µsec |
| Overload Recovery | 50% Output Overload | | 0.2 | | | • | | | • | | µsec |
| **INPUT CHARACTERISTICS** | | | | | | | | | | | |
| Input Voltage Range | | | | | | | | | | | |
| Rated Operation | | ±10 | | | • | | | • | | | V |
| Absolute Maximum | | | | ±Vcc | | | • | | | • | V |
| Input Resistance | X, Y, Z(1) | | 10 | | | • | | | • | | MΩ |
| Input Bias Current | X, Y, Z | | 1.4 | | | • | | | • | | µA |
| **OUTPUT CHARACTERISTICS** | | | | | | | | | | | |
| Rated Output | | | | | | | | | | | |
| Voltage | $I_o = \pm5mA$ | ±10 | | | • | | | • | | | V |
| Current | $V_o = \pm10V$ | ±5 | | | • | | | • | | | mA |
| Output Resistance | f = DC | | 1.5 | | | • | | | • | | Ω |
| **OUTPUT NOISE VOLTAGE** | X = Y = 0 | | | | | | | | | | |
| $f_o$ = 1Hz | | | 40 | | | • | | | • | | $\mu V/\sqrt{Hz}$ |
| $f_o$ = 10kHz | | | 1.0 | | | • | | | • | | $\mu V/\sqrt{Hz}$ |
| 1/f Corner Frequency | | | 1060 | | | • | | | • | | Hz |
| $f_B$ = 10Hz to 10kHz | | | 125 | | | • | | | • | | µV, rms |
| $f_B$ = 10Hz to 10MHz | | | 3 | | | • | | | • | | mV, rms |
| **POWER SUPPLY REQUIREMENTS** | | | | | | | | | | | |
| Rated Voltage | | | ±15 | | | • | | | • | | VDC |
| Operating Range | Derated Performance | ±8.5 | | ±20 | • | | • | • | | • | VDC |
| Quiescent Current | | | ±5.5 | | | • | | | • | | mA |

## ELECTRICAL (CONT)

| MODEL | | 4213AM | | | 4213BM | | | 4213SM | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PARAMETER | CONDITIONS | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | UNITS |
| **TEMPERATURE RANGE** (Ambient) | | | | | | | | | | | |
| Specification | | -25 | | +85 | * | | * | -55 | | +125 | °C |
| Operating Range | Derated Performance | -55 | | +125 | * | | * | * | | * | °C |
| Storage | | -65 | | +150 | * | | * | * | | * | °C |

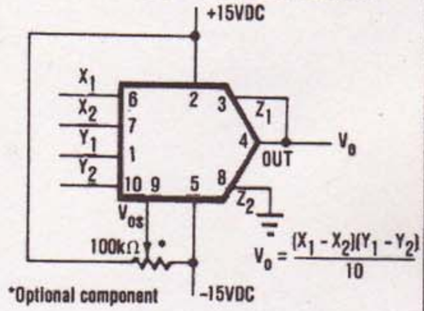
NOTES:

1. $Z_2$ input resistance is 10MΩ, typical, with Pin 9 open. If Pin 9 is grounded or used for optional offset adjustment, the $Z_2$ input resistance may be as low as 25kΩ.

*Same as 4213AM specification.

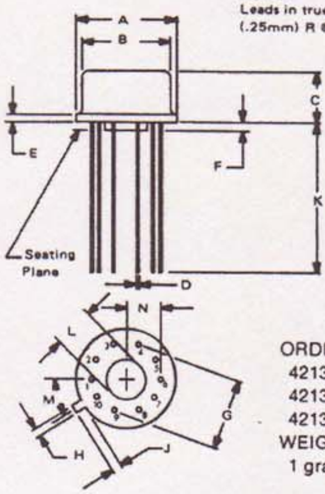


### CONNECTION DIAGRAM




### MECHANICAL

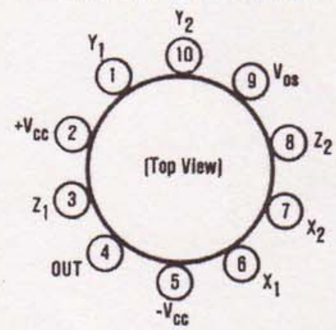
NOTE:
Leads in true position within .010" (.25mm) R @ MMC at seating plane.




ORDER NUMBER:
4213AM
4213BM
4213SM
WEIGHT:
1 gram

| DIM | INCHES MIN | INCHES MAX | MILLIMETERS MIN | MILLIMETERS MAX |
|---|---|---|---|---|
| A | .335 | .370 | 8.51 | 9.40 |
| B | .305 | .335 | 7.75 | 8.51 |
| C | .165 | .185 | 4.19 | 4.70 |
| D | .016 | .021 | 0.41 | 0.53 |
| E | .010 | .040 | 0.25 | 1.02 |
| F | .010 | .040 | 0.25 | 1.02 |
| G | .230 BASIC | | 5.84 BASIC | |
| H | .028 | .034 | 0.71 | 0.86 |
| J | .029 | .045 | 0.74 | 1.14 |
| K | .500 | -- | 12.70 | -- |
| L | .120 | .160 | 3.05 | 4.06 |
| M | 36° BASIC | | 36° BASIC | |
| N | .110 | .120 | 2.79 | 3.05 |

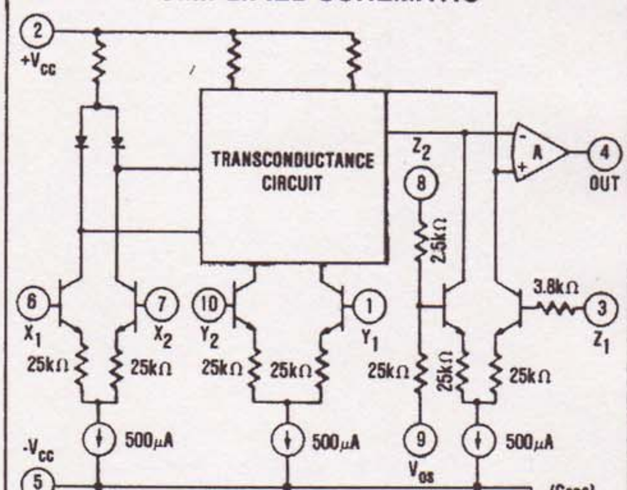
### PIN CONFIGURATION



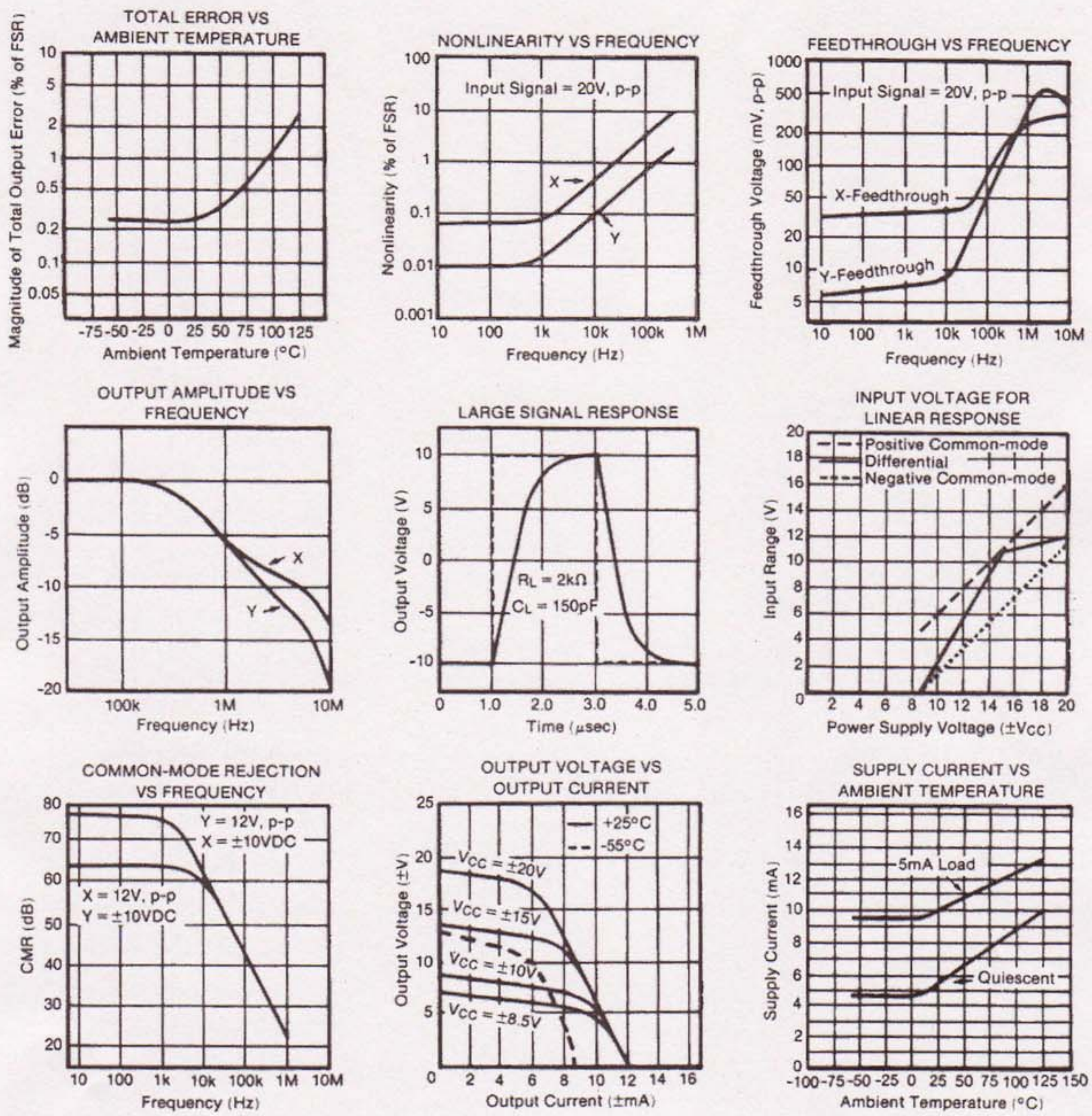

NOTES:

1. $V_{os}$ adjustment optional not normally recommended. $V_{os}$ pin may be left open or grounded.
2. All unused input pins should be grounded.
3. Pin 5 is connected to the case.

### SIMPLIFIED SCHEMATIC



# TYPICAL PERFORMANCE CURVES




## ABSOLUTE MAXIMUM RATINGS

| | |
|---|---|
| Supply | ±20VDC |
| Internal Power Dissipation(1) | 500mW |
| Differential Input Voltage(2) | ±40VDC |
| Input Voltage Range(2) | ±20VDC |
| Storage Temperature Range | -65°C to +150°C |
| Operating Temperature Range | -55°C to +125°C |
| Lead Temperature (soldering, 10 seconds) | +300°C |
| Output Short-circuit Duration(3) | Continuous |
| Junction Temperature | +150°C |

NOTES:

1. Package must be derated based on: $\theta_{JC}$ = 55°C/W and $\theta_{JA}$ = 165°C/W.
2. For supply voltages less than ±20VDC the absolute maximum input voltage is equal to the supply voltage.
3. Short-circuit may be to ground only. Rating applies to +85°C ambient.

# DEFINITIONS

### TOTAL ERROR (Accuracy)

Total error is the actual departure of the multiplier output voltage from the ideal product of its input voltages. It includes the sum of the effects of input and output DC offsets, gain error and nonlinearity.

### OUTPUT OFFSET

Output offset is the output voltage when both inputs $V_X$ and $Y_Y$ are zero volts.

### SCALE FACTOR ERROR

Scale factor error is the difference between the actual scale factor and the ideal scale factor.

### NONLINEARITY

Nonlinearity is the maximum deviation from a best straightline (curve fitting on input-output graph) expressed as a percent of peak-to-peak full scale output.

### FEEDTHROUGH

Feedthrough is the signal at the output for any value of $V_X$ or $V_Y$ within the rated range, when the other input is zero.

### SMALL SIGNAL BANDWIDTH

Small signal bandwidth is the frequency at which the output is down 3dB from its low frequency value for a nominal output amplitude of 10% of full scale.

### 1% AMPLITUDE ERROR

The 1% amplitude error is the frequency the output amplitude is in error by 1%, measured with an output amplitude of 10% of full scale.

### 1% VECTOR ERROR

The 1% vector error is the frequency at which a phase error of 0.01 radians (0.57°) occurs. This is the most sensitive measure of dynamic error of a multiplier.

# APPLICATIONS INFORMATION

### MULTIPLICATION

Figure 1 shows the basic connection for four-quadrant multiplication.

The 4213 meets all of its specifications without trimming. Accuracy can, however, be improved by nulling the output offset voltage using the 100kΩ optional balance potentiometer shown in Figure 1.

AC feedthrough may be reduced to a minimum by applying an external voltage to the X or Y input as shown in Figure 2.

$Z_2$, the optional summing input, may be used to sum a voltage into the output of the 4213. If not used, this terminal, as well as the X and Y input terminals, should be grounded. All inputs should be referenced to power supply common.

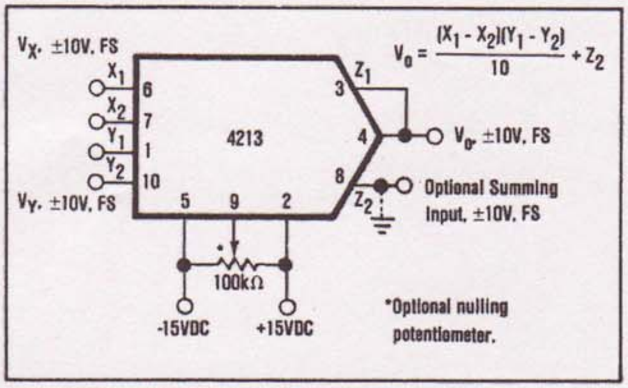



FIGURE Multiplier Connection.

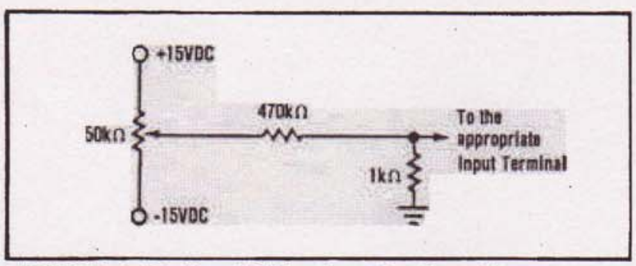



FIGURE 2. Optional Trimming Configuration.

Figure 3 shows how to achieve a scale factor larger than the nominal 0.1. In this case, the scale factor is unity which makes the transfer function

$$V_o = KV_XV_Y = K(X_1 - X_2)(Y_1 - Y_2)$$
$$K = [1 + (R_1/R_2)]/10$$
$$0.1 \leqslant K \leqslant 1$$

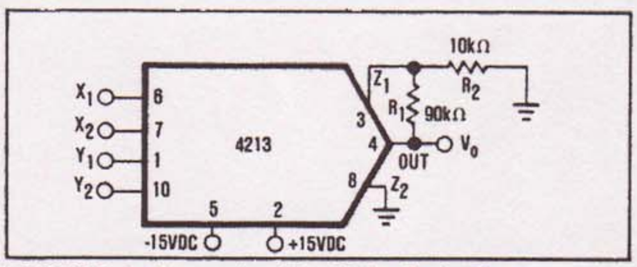



FIGURE 3. Connection For Unity Scale Factor.

This circuit has the disadvantage of increasing the output offset voltage by a factor of 10 which may require the use of the optional balance control for some applications. In addition, this connection reduces the small signal bandwidth to about 50kHz.

### DIVISION

Figure 4 shows the basic connection for two-quadrant division. This configuration is a multiplier-inverted analog divider, i.e., a multiplier connected in the feedback loop of an operational amplifier. In the case of the 4213 this operational amplifier is the output amplifier of the multiplier itself.

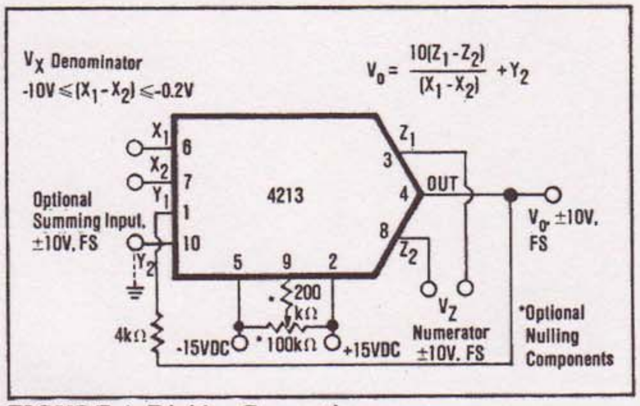



FIGURE 4. Divider Connection.

The divider error with a multiplier-inverted analog divider is approximately

$$\epsilon_{divider} = 10\ \epsilon_{multiplier}/(X_1 - X_2).$$

It is obvious from this error equation that divider error becomes excessively large for small values of $X_1 - X_2$. A 10-to-1 denominator range is usually the practical limit. If more accurate division is required over a wide range of denominator voltages, an externally generated voltage may be applied to the unused X-input (see Optional Trim Configuration). To trim, apply a ramp of +100mV to +1V at 100Hz to both $X_1$ and $Z_1$ if $X_2$ is used for offset adjustment, otherwise reverse the signal polarity, and adjust the trim voltage to minimize the variation in the output. An alternative to this procedure would be to use the Burr-Brown DIV100, a precision log-antilog divider.

## SQUARING

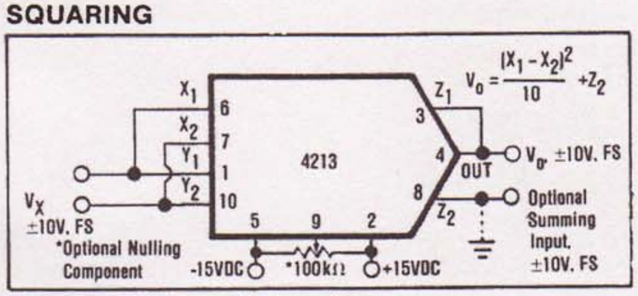



FIGURE 5. Squarer Connection.

## SQUARE ROOT

Figure 6 shows the connection for taking the square root of the voltage $V_Z$. The diode prevents a latching condition which could occur if the input momentarily changed polarity. This latching condition is not a design flaw in the 4213, but occurs when a multiplier is connected in the feedback loop of an operational amplifier to perform square root functions.

The load resistance $R_L$ must be in the range of $10k\Omega \leq R_L \leq 1M\Omega$. This resistance must be in the circuit as it provides the current necessary to operate the diode.

The output offset should be nulled for optimum performance by allowing the input to be its smallest expected value and adjusting $R_1$ for the proper output voltage.

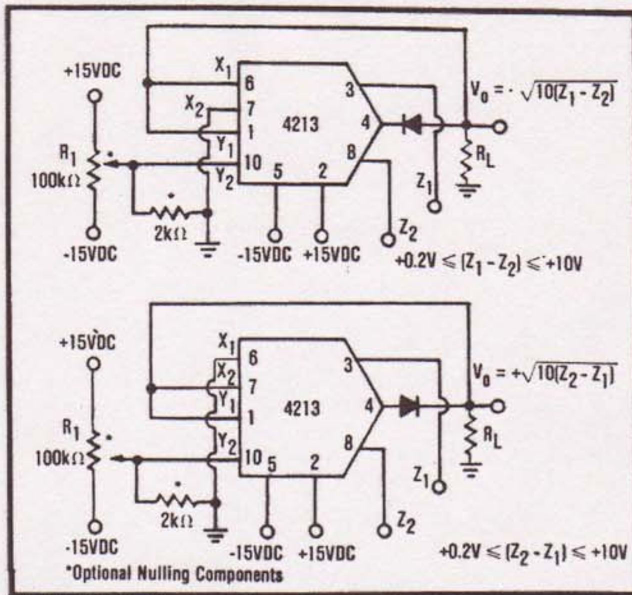



FIGURE 6. Square Root Connection.

This will improve the square root mode accuracy to about that of the multiply mode.

## BRIDGE LINEARIZATION

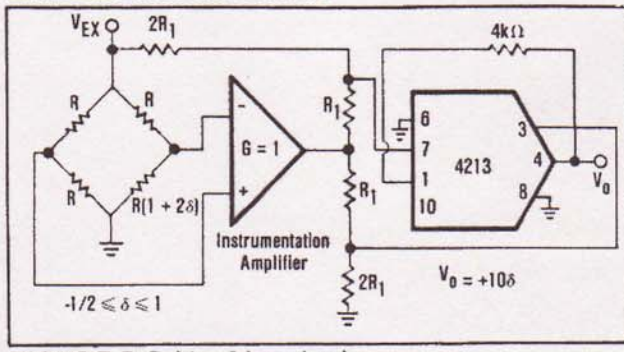



FIGURE 7. Bridge Linearization.

The use of the 4213 and the instrumentation amplifier to linearize the output from a bridge circuit makes the output $V_o$ independent of the bridge supply voltage.

## TRUE RMS-TO-DC CONVERSION

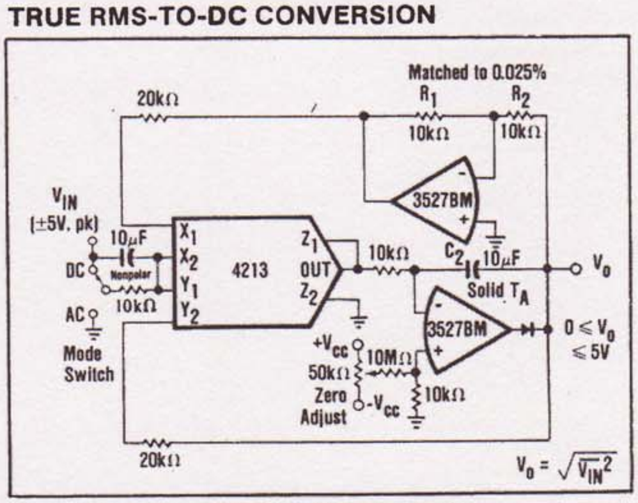



FIGURE 8. True RMS-to-DC Conversion.

The RMS-to-DC conversion circuit of Figure 8 gives greater accuracy and bandwidth but with less dynamic range than most rms-to-DC converters.

## PERCENTAGE COMPUTATION

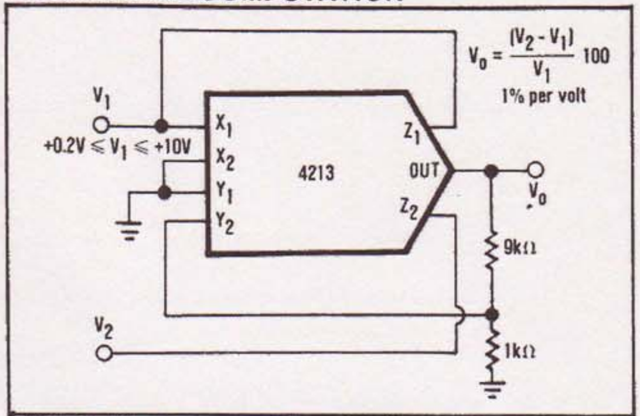



FIGURE 9. Percentage Computation.

The circuit of Figure 9 has a sensitivity of 1V/% and is capable of measuring 10% deviations. Wider deviation can be measured by decreasing the ratio of $R_2/R_1$.

## SINE FUNCTION GENERATOR

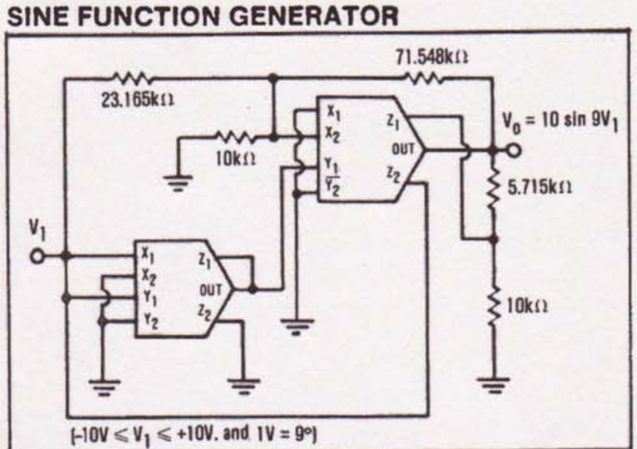



FIGURE 10. Sine Function Generator.

The circuit in Figure 10 uses implicit feedback to implement the following sine function approximation:

$$V_o = (1.5715V_1 - 0.004317V_1^3)/(1 + 0.001398V_1^2)$$
$$= 10 \sin(9V_1).$$

## SINGLE-PHASE POWER MEASUREMENT

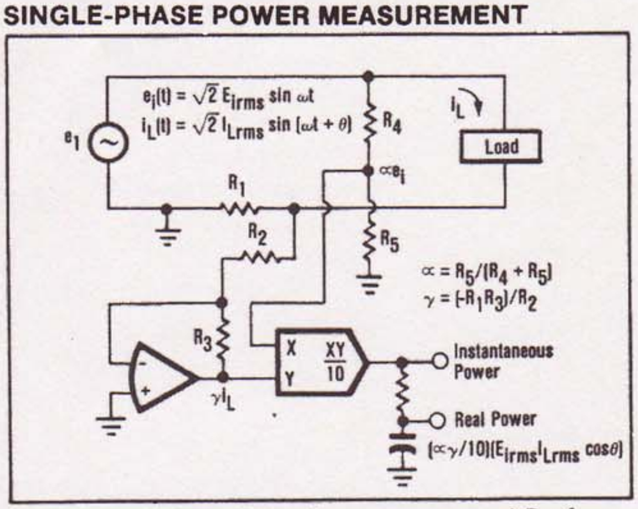



FIGURE 11. Single-Phase Instantaneous and Real Power Measurement.

## WIRING PRECAUTIONS

In order to prevent frequency instability due to lead inductance of the power supply lines, each power supply should be bypassed. This should be done by connecting a 10μF tantalum capacitor in parallel with a 1000pF ceramic capacitor from the $+V_{CC}$ and $-V_{CC}$ pins of the 4213 to the power supply common. The connection of these capacitors should be as close to the 4213 as practical.

## CAPACITIVE LOADS

Stable operation is maintained with capacitive loads to 1000pF in all modes typically, except the square root mode for which 50pF is a safe upper limit. Higher capacitive loads can be driven if a 100Ω resistor is connected in series with the 4213's output.

## MORE CIRCUITS

The theory and procedures for developing virtually any function generator or linearization circuit can be found in the Burr-Brown/ McGraw Hill book "FUNCTION CIRCUITS - Design and Applications."

## PACKAGING INFORMATION

| Orderable part number | Status (1) | Material type (2) | Package \| Pins | Package qty \| Carrier | RoHS (3) | Lead finish/ Ball material (4) | MSL rating/ Peak reflow (5) | Op temp (°C) | Part marking (6) |
|---|---|---|---|---|---|---|---|---|---|
| 4213SM | Last Time Buy | Production | TO-100 (LME) \| 10 | 20 \| TUBE | Yes | AU | N/A for Pkg Type | - | 4213SM |
| 4213SM.A | NRND | Production | TO-100 (LME) \| 10 | 20 \| TUBE | Yes | AU | N/A for Pkg Type | See 4213SM | 4213SM |

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(4) **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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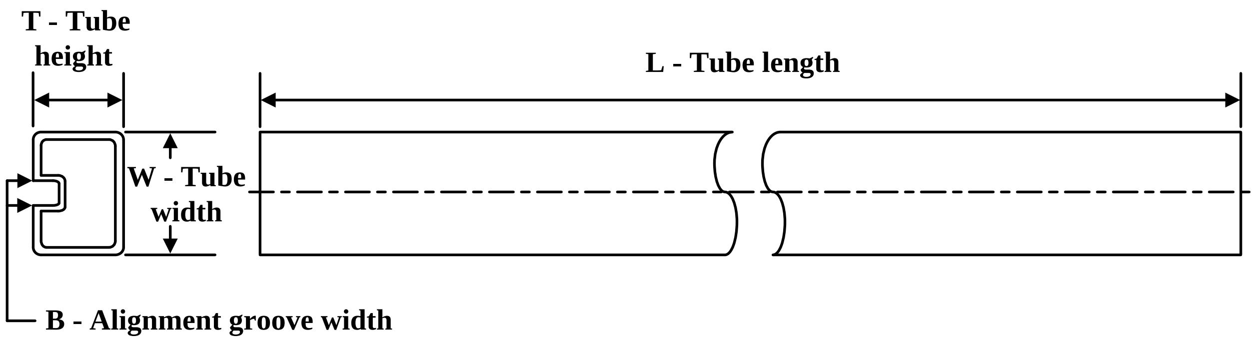
## TUBE




*All dimensions are nominal

| Device | Package Name | Package Type | Pins | SPQ | L (mm) | W (mm) | T (µm) | B (mm) |
|---|---|---|---|---|---|---|---|---|
| 4213SM | LME | TO-CAN | 10 | 20 | 532.13 | 21.59 | 889 | NA |
| 4213SM.A | LME | TO-CAN | 10 | 20 | 532.13 | 21.59 | 889 | NA |

# IMPORTANT NOTICE AND DISCLAIMER