



MULTIPLIER-DIVIDER

FEATURES

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

APPLICATIONS

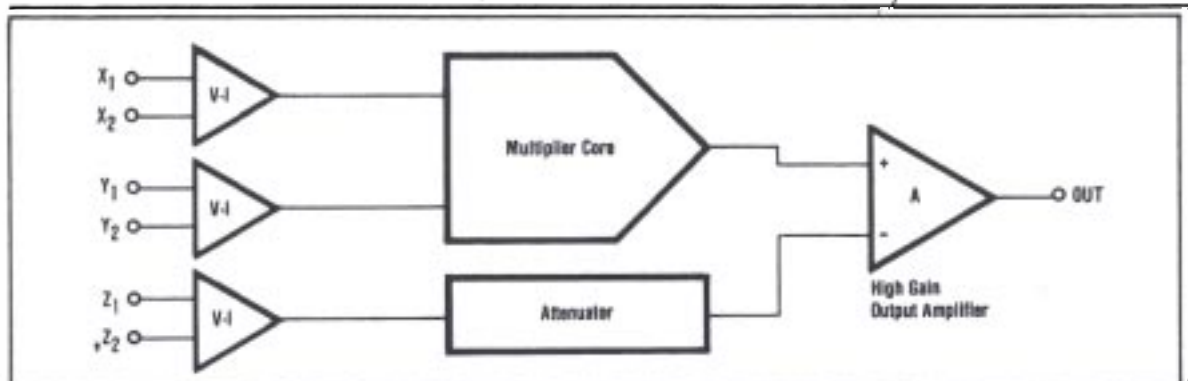
- MULTIPLICATION
- DIVISION
- SQUARING
- SQUARE ROOT
- LINEARIZATION
- POWER COMPUTATION
- ANALOG SIGNAL PROCESSING
- ALGEBRAIC COMPUTATION
- TRUE RMS-TO-DC CONVERSION

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



SPECIFICATIONS

ELECTRICAL

Specifications at $T_A = +25^\circ\text{C}$ and $\pm V_{CC} = 15\text{VDC}$ unless otherwise noted.

MODEL	PARAMETER	CONDITIONS	4213AM			4213BM			4213SM			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
MULTIPLIER PERFORMANCE												
	Transfer Function		$\frac{(X_1 - X_2)(Y_1 - Y_2) + Z_2}{10}$									
	Total Error	$-10\text{V} \leq X, Y \leq 10\text{V}$ $T_A = +25^\circ\text{C}$			± 1.0						± 0.5	% FSR
	Initial	$-25^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$		± 0.008	± 0.02							% FSR/ $^\circ\text{C}$
	vs Temperature	$-55^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$							± 0.025		± 0.05	% FSR/ $^\circ\text{C}$
	vs Supply			± 0.05								% FSR/%
	Individual Errors											
	Output Offset											
	Initial	$T_A = +25^\circ\text{C}$		± 10	± 50		± 7	± 25		± 7	± 25	mV
	vs Temperature	$-25^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$		± 0.7	± 2.0		± 0.3	± 0.7				mV/ $^\circ\text{C}$
	vs Temperature	$-55^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$							± 0.3		± 0.7	mV/ $^\circ\text{C}$
	vs Supply			± 0.25								mV/%
	Scale Factor Error											
	Initial	$T_A = +25^\circ\text{C}$		± 0.12								% FSR
	vs Temperature	$-25^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$		± 0.008								% FSR/ $^\circ\text{C}$
	vs Temperature	$-55^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$							± 0.008			% FSR/ $^\circ\text{C}$
	vs Supply			± 0.05								% FSR/%
	Nonlinearity											
	X Input	$X = 20\text{V}, p-p; Y = \pm 10\text{VDC}$		± 0.08								% FSR
	Y Input	$Y = 20\text{V}, p-p; X = \pm 10\text{VDC}$		± 0.01								% FSR
	Feedthrough	$f = 50\text{Hz}$										
	X Input	$X = 20\text{V}, p-p; Y = 0$		30								mV, p-p
	Y Input	$Y = 20\text{V}, p-p; X = 0$		6								mV, p-p
	vs Temperature	$-25^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$		0.1								mV, p-p/ $^\circ\text{C}$
	vs Temperature	$-55^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$							0.1			mV, p-p/ $^\circ\text{C}$
	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)	$X = -10\text{V}$ $-10\text{V} \leq Z \leq +10\text{V}$ $X = -1\text{V}$ $-1\text{V} \leq Z \leq +1\text{V}$ $-10\text{V} \leq X \leq -0.2\text{V}$ $-10\text{V} \leq Z \leq +10\text{V}$		± 0.75			± 0.35			± 0.35		% FSR
				± 2.0			± 1.0			± 1.0		% FSR
				± 5.0			± 1.0			± 1.0		% FSR
SQUARER PERFORMANCE												
	Transfer Function			$\frac{(X_1 - X_2)^2}{10} + Z_2$								
	Total Error	$-10\text{V} \leq X \leq +10\text{V}$		± 0.6			± 0.3			± 0.3		% FSR
SQUARE-ROOTER PERFORMANCE												
	Transfer Function	$Z_1 < Z_2$		$+\sqrt{10(Z_2 - Z_1)}$								
	Total Error	$1\text{V} \leq Z \leq 10\text{V}$		± 1			± 0.5			± 0.5		% FSR
AC PERFORMANCE												
	Small-Signal Bandwidth	$\pm 3\text{dB}$		550								kHz
	1% Amplitude Error	Small Signal		70								kHz
	1% (0.57°) Vector Error	Small Signal		5								kHz
	Full Power Bandwidth	$ V_d = 10\text{V}, R_L = 2\text{k}\Omega$		320								kHz
	Slew Rate	$ V_d = 10\text{V}, R_L = 2\text{k}\Omega$		20								V/ μsec
	Settling Time	$e = \pm 1\%, \Delta V_0 = 20\text{V}$		2								μsec
	Overload Recovery	50% Output Overload		0.2								μsec
INPUT CHARACTERISTICS												
	Input Voltage Range			± 10								V
	Rated Operation					$\pm V_{CC}$						V
	Absolute Maximum											V
	Input Resistance	X, Y, Z(1)		10								M Ω
	Input Bias Current	X, Y, Z		1.4								μA
OUTPUT CHARACTERISTICS												
	Rated Output Voltage	$I_o = \pm 5\text{mA}$		± 10								V
	Current	$V_o = \pm 10\text{V}$		± 5								mA
	Output Resistance	$I = \text{DC}$		1.5								Ω
		$X = Y = 0$										
				40								$\mu\text{V}/\sqrt{\text{Hz}}$
				1.0								$\mu\text{V}/\sqrt{\text{Hz}}$
				1060								Hz
				125								$\mu\text{V}, \text{rms}$
				3								mV, rms
MENTS												
	Rated Voltage			± 15								VDC
	Operating Range	Derated Performance		± 8.5		± 20						VDC
	Quiescent Current			± 5.5								mA

NOTES:

1. Z_2 input resistance is $10M\Omega$, 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 $25k\Omega$.

*Same as 4213AM specification.

The information provided herein is believed to be reliable; however, BURR-BROWN assumes no responsibility for inaccuracies or omissions. BURR-BROWN assumes no responsibility for the use of this information, and all use of such information shall be entirely at the user's own risk. Prices and specifications are subject to change without notice. No patent rights or licenses to any of the circuits described herein are implied or granted to any third party. BURR-BROWN does not authorize or warrant any BURR-BROWN product for use in life support devices and/or systems.

TYPICAL PERFORMANCE CURVES

NOTES:

1. Package must be derated based on: $\theta_{JC} = 55^{\circ}\text{C/W}$ and $\theta_{JA} = 165^{\circ}\text{C/W}$.
2. For supply voltages less than $\pm 20\text{VDC}$ the absolute maximum input voltage is equal to the supply voltage.
3. Short-circuit may be to ground only. Rating applies to $+85^{\circ}\text{C}$ 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 V_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 100k Ω 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 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

$$V_o = KV_X V_Y = K(X_1 - X_2)(Y_1 - Y_2)$$

$$K = [1 + (R_1/R_2)]/10$$

$$0.1 \leq K \leq 1$$

FIGURE 1 Multiplier Connection.

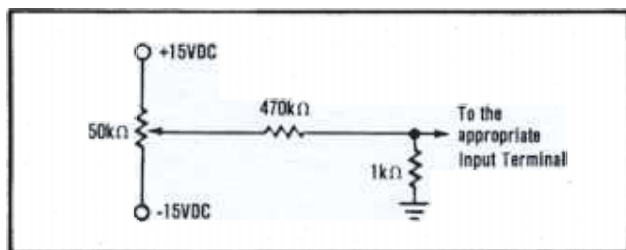


FIGURE 2. Optional Trimming Configuration.

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

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

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_L for the proper output voltage.

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:

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

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 10 μ F 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 100 Ω 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 DEVICE	STATUS(1)	PACKAGE TYPE	PACKAGE DRAWING	PINS	PACKAGE QTY
4213AM	NRND	TO/SOT	LME	10	20
4213AM2	OBSOLETE	TO/SOT	LMC	8	
4213BM	NRND	TO/SOT	LME	10	20
4213BM1	OBSOLETE	TO/SOT	LMC	8	
4213SM	NRND	TO/SOT	LME	10	20

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSOLETE: TI has discontinued the production of the device.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products		Applications	
Amplifiers	amplifier.ti.com	Audio	www.ti.com/audio
Data Converters	dataconverter.ti.com	Automotive	www.ti.com/automotive
DSP	dsp.ti.com	Broadband	www.ti.com/broadband
Interface	interface.ti.com	Digital Control	www.ti.com/digitalcontrol
Logic	logic.ti.com	Military	www.ti.com/military
Power Mgmt	power.ti.com	Optical Networking	www.ti.com/opticalnetwork
Microcontrollers	microcontroller.ti.com	Security	www.ti.com/security
		Telephony	www.ti.com/telephony
		Video & Imaging	www.ti.com/video
		Wireless	www.ti.com/wireless

Mailing Address: Texas Instruments
Post Office Box 655303 Dallas, Texas 75265

Copyright © 2003, Texas Instruments Incorporated