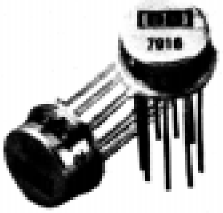
4213



MULTIPLIER-DIVIDER

FEATURES

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

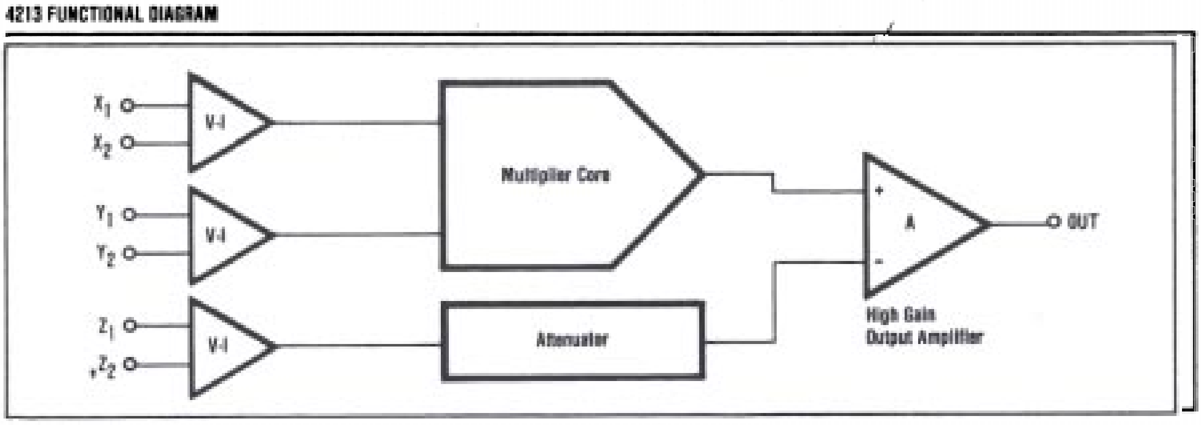
APPLICATIONS

- 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



Printed in U.S.A. December, 1985

SPECIFICATIONS

ELECTRICAL

Specifications at T_A = +25°C and $\pm V_{CC}$ = 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 ≤ X, Y ≤ 10V										
Initial	T_A = +25°C			±1.0			±0.5			±0.5	% FSR
vs Temperature	-25°C ≤ T_A ≤ +85°C		±0.008	±0.02		•	•		--	--	% FSR/°C
vs Temperature	-55°C ≤ T_A ≤ +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 ≤ T_A ≤ +85°C		±0.7	±2.0		±0.3	±0.7		--	--	mV/°C
vs Temperature	-55°C ≤ T_A ≤ +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 ≤ T_A ≤ +85°C		±0.008			•			--		% FSR/°C
vs Temperature	-55°C ≤ T_A ≤ +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 ≤ T_A ≤ +85°C		0.1			•			--		mV, p-p/°C
vs Temperature	-55°C ≤ T_A ≤ +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 -10V ≤ Z ≤ +10V		±0.75			±0.35			±0.35		% FSR
	X = -1V -1V ≤ Z ≤ +1V		±2.0			±1.0			±1.0		% FSR
	-10V ≤ X ≤ -0.2V -10V ≤ Z ≤ +10V		±5.0			±1.0			±1.0		% FSR
SQUARER PERFORMANCE											
Transfer Function		$\frac{(X_1-X_2)^2}{10}+Z_2$				•			•		
Total Error	-10V ≤ X ≤ +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 ≤ Z ≤ 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	$\lvert V_0 \rvert$ = 10V, R_L = 2kΩ		320			•			•		kHz
Slew Rate	$\lvert V_0 \rvert$ = 10V, R_L = 2kΩ		20			•			•		V/µsec
Settling Time	ϵ = ±1%, ΔV_0 = 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 = ±5mA	±10			•			•			V
Current	V_0 = ±10V	±5			•			•			mA
Output Resistance	f = DC		1.5			•			•		Ω
	. X = Y = 0										
			40			•			•		µV/√Hz
			1.0			•			•		µV/√Hz
			1060			•			•		Hz
			125			•			•		µV, 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 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.

TYPICAL PERFORMANCE CURVES

NOTES:
1. Package must be derated based on: θ_{JC} = 55°C/W and θ_{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.

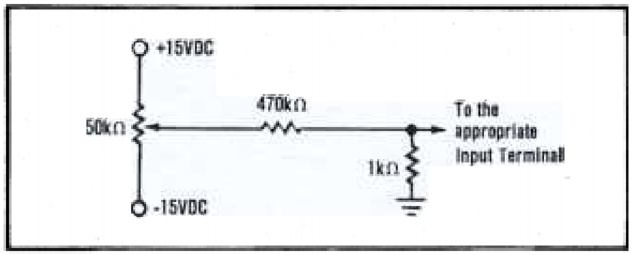


FIGURE 2. Optional Trimming Configuration.

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 $10k\Omega \leqslant R_L \leqslant 1M\Omega$. 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.

. 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."

PACKAGE OPTION ADDENDUM

3-Oct-2003

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.

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