# TMC2272

# Digital Colorspace Converter/Corrector

## 36 Bit Color (12 Bits x 3 Components) 40MHz

A 40MHz, three-channel, 36 bit (three 12-bit components) colorspace converter and color corrector, the TMC2272 uses 9 parallel multipliers to process high-resolution imagery in real time.

The TMC2272 also operates at any slower clock rate and with any smaller data path width, allowing it to handle all broadcast and consumer camera, frame-grabber, encoder/decoder, recorder and monitor applications as well as most electronic imaging applications.

The TMC2272's processing ability allows colorspaces to be optimized for every input or output device; camera, monitor, transmission or storage medium in real time, regardless of the signal format required by each stage in a system. For instance, a frame buffer may be operated in any desired colorspace in an otherwise RGB system with the use of two TMC2272s for translation to and from the desired frame-buffer colorspace.

A complete set of three 12-bit samples is processed on every clock cycle, with a five-cycle pipeline latency. Full 23-bit (for each of three components) internal precision is provided with 10-bit user-defined coefficients. The coefficients may be varied dynamically, with three new coefficients loaded every clock cycle. (The full set of nine can be replaced in three clock cycles.) Rounding to 12 bits per component is performed only at the final output. This allows full accuracy with correct rounding and overflow headroom for applications that require less than 12-bit per component. All inputs and outputs are registered on the rising edges of the clock.

The TMC2272 is fabricated in TRW's OMICRON-C™ 1µ CMOS process and has fully guaranteed performance over the full commercial temperature range of 0 to 70°C, and all other operational conditions specified in the ***Operating conditions*** table. The TMC2272 is available in a 121-pin plastic pin-grid array (PPGA) package in three speed grades.

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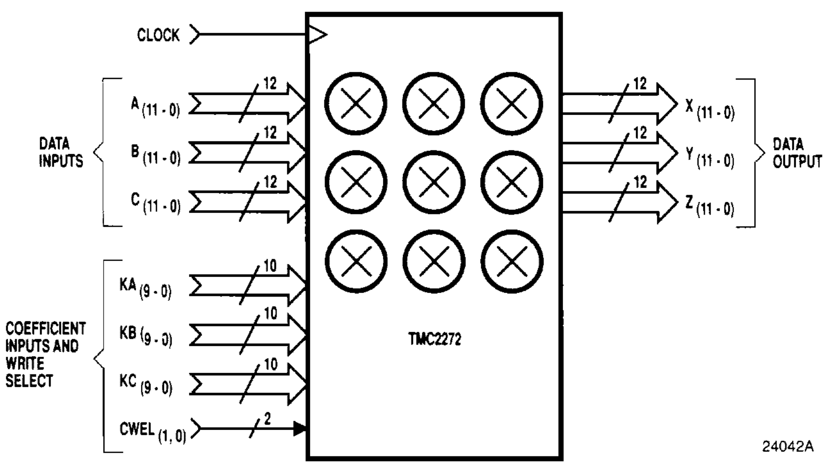
## Logic Symbol



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## Features

- 40MHz (25ns) Pipelined Throughput
- 3 Simultaneous 12-Bit Input And Output Channels (64 Giga [$2^{36}$] Colors)
- Two's Complement Inputs And Outputs
- Overflow Headroom Available In Lower Resolution
- 10-Bit User-Defined Coefficients
- TTL-Compatible Input And Output Signals
- Full Precision Internal Calculation
- Output Rounding
- On-Board Coefficient Memory
- OMICRON-C™ 1μ CMOS process

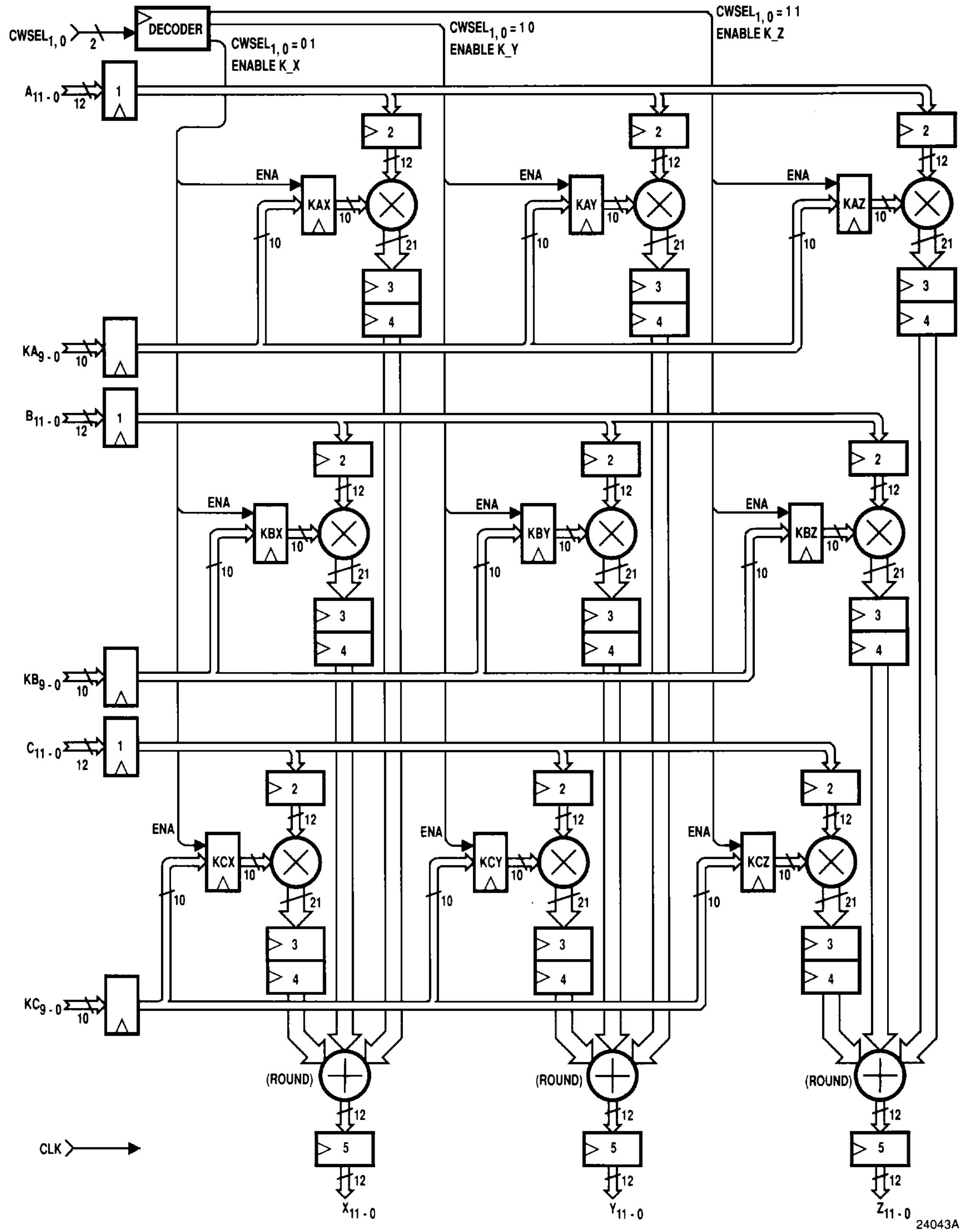
## Applications

- Translation Between Component Color Standards (RGB, YIQ, YUV, etc.)
- Broadcast Composite Color Encoding And Decoding (All Standards)
- Broadcast Composite Color Standards Conversion And Transcoding
- Camera Tube And Monitor Phosphor Colorimetry Correction
- White Balancing And Color-Temperature Conversion
- Image Capture, Processing and Storage
- Color Matching Between Systems, Cameras And Monitors
- Three-Dimensional Perspective Translation

## Associated Products

- TDC1058 A/D Converter
- TDC1049 A/D Converter
- TMC2242 Interpolator/Decimator
- TMC2330 Rectangular/Polar Converter
- TDC1012 D/A Converter
- TMC0171 D/A Converter

## Figure 1. Functional Block Diagram



## Functional Description

### General Information

The TMC2272 is a nine-multiplier array with the internal bus structure and summing adders needed to implement a 3 x 3 matrix multiplier (triple dot product). With a 40MHz guaranteed maximum clock rate, this device offers video and imaging system designers a single-chip solution to numerous common image and signal-processing problems.

The three data input ports ($A_{11-0}$, $B_{11-0}$, $C_{11-0}$) accept 12-bit two's complement integer data, which is also the format for the output ports ($X_{11-0}$, $Y_{11-0}$, and $Z_{11-0}$). Other format and path width options are discussed in the numeric format and overflow section. The coefficient input ports (KA, KB, KC) are always 10-bit two's complement fractional. *Table 2* details the bit weighting.

Full precision is maintained throughout the TMC2272. Each output is accurately rounded to 12-bits from the 23-bits entering the final adder.

### Signal Definitions

| | |
|---|---|
| A(n), B(n), C(n) | Indicates the data word presented to that input port during the specified clock rising edge (n). Applies to input ports $A_{11-0}$, $B_{11-0}$, and $C_{11-0}$. |
| KAX(n) thru KCZ(n) | Indicates coefficient value stored in the specified one of the nine onboard coefficient registers KAX through KCZ, input during or before the specified clock rising edge (n). |
| X(n), Y(n), Z(n) | Indicates data available at that output port $t_{DO}$ after the specified clock rising edge (n). Applies to output ports $X_{11-0}$, $Y_{11-0}$, and $Z_{11-0}$. |

The TMC2272 utilizes six input and output ports to realize a "triple dot product," in which each output is the sum of all three input words in multiplied by the appropriate stored coefficients. The three corresponding sums of products are available at the outputs five clock cycles after the input data are latched, and three new data words rounded to 12-bits are then available every clock cycle. See the *Applications Discussion* regarding encoded video standard conversion matrices.

X(5) = A(1)KAX(1) + B(1)KBX(1) + C(1)KCX(1)
Y(5) = A(1)KAY(1) + B(1)KBY(1) + C(1)KCY(1)
Z(5) = A(1)KAZ(1) + B(1)KBZ(1) + C(1)KCZ(1)

### Pin Definitions

#### Power

| | |
|---|---|
| $V_{DD}$, GND | The TMC2272 operates from a single +5V supply. All pins must be connected. |

#### Control

| | |
|---|---|
| $CWSEL_{1-0}$ | This input selects which three of the 9 coefficient registers, if any, will be updated on the next clock cycle from the $KA_{9-0}$, $KB_{9-0}$ and $KC_{9-0}$ inputs. See *Table 4* and the *Functional Block Diagram*. |

#### Clock

| | |
|---|---|
| CLK | The TMC2272 operates from a single system clock input. All timing specifications are referenced to the rising edge of clock. |

#### Data and Coefficient Inputs

| | |
|---|---|
| $A_{11-0}$, $B_{11-0}$, $C_{11-0}$ | These are the three 12-bit wide data input ports. |
| $KA_{9-0}$, $KB_{9-0}$, $KC_{9-0}$ | These are the 10-bit wide coefficient input ports. The value at each of these three inputs will update one coefficient register as selected by the coefficient write select ($CWSEL_{1-0}$) on the next clock. See *Table 1* and the *Functional Block Diagram*. |

#### Outputs

| | |
|---|---|
| $X_{11-0}$, $Y_{11-0}$, $Z_{11-0}$ | These are the data outputs. Data are available at the 12-bit registered Output Ports X, Y, and Z $t_{DO}$ after every clock rising edge. |

## Table 1. Coefficient Loading

| | | CWSEL$_{1,0}$ | | | |
|---|---|---|---|---|---|
| | | 00 | 01 | 10 | 11 |
| Input | $KA_{9-0}$ | Hold All | Load KAX | Load KAY | Load KAZ |
| Input | $KB_{9-0}$ | Hold All | Load KBX | Load KBY | Load KBZ |
| Input | $KC_{9-0}$ | Hold All | Load KCX | Load KCY | Load KCZ |

## Package Interconnections

| Signal Type | Signal Name | Function | H5 Package |
|---|---|---|---|
| Power | $V_{DD}$ | Supply Voltage | F3, H3, L7, C8, C4 |
| | GND | Ground | E3, G3, J3, L4, L6, H11, C7, C5, A4, B5 |
| Clock | CLK | System Clock | D11 |
| Controls | $CWSEL_{1,0}$ | Coefficient Write Select | J12, J13 |
| Inputs | $A_{11-0}$ | Data Input A | E11, D13, E12, E13, F11, F12, F13, G13, G11, G12, H13, H12 |
| | $B_{11-0}$ | Data Input B | B10, A11, B11, C10, A12, B12, C11, A13, C12, B13, C13, D12 |
| | $C_{11-0}$ | Data Input C | A5, C6, B6, A6, A7, B7, A8, B8, A9, B9, A10, C9 |
| | $KA_{9-0}$ | Coefficient Input KAX, KAY, or KAZ (See Pin Definitions and Table 1) | K13, J11, K12, L13, L12, K11, M13, M12, L11, N13 |
| | $KB_{9-0}$ | Coefficient Input KBX, KBY, or KBZ (See Pin Definitions and Table 1) | M11, L10, N12, N11, M10, L9, N10, M9, N9, L8 |
| | $KC_{9-0}$ | Coefficient Input KCX, KCY, or KCZ (See Pin Definitions and Table 1) | M8, N8, N7, M7, N6, M6, N5, M5, N4, L5 |
| Outputs | $X_{11-0}$ | Output X | B4, A3, A2, B3, A1, C3, B2, B1, D3, C2, C1, D2 |
| | $Y_{11-0}$ | Output Y | D1, E2, E1, F2, F1, G2, G1, H1, K1, J2, J1, H2 |
| | $Z_{11-0}$ | Output Z | M4, N3, M3, N2, M2, L3 N1, L2, K3, M1, L1, K2 |

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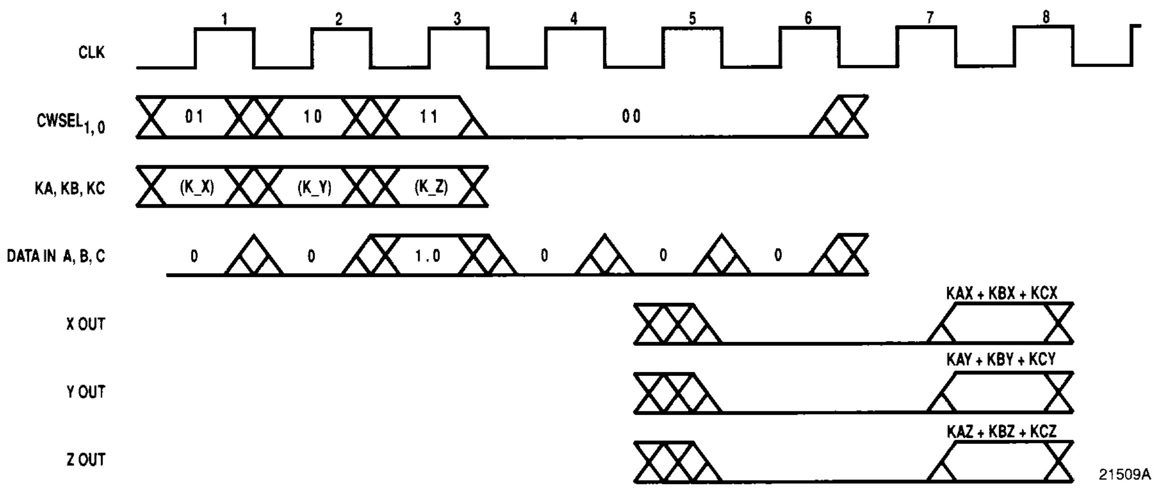
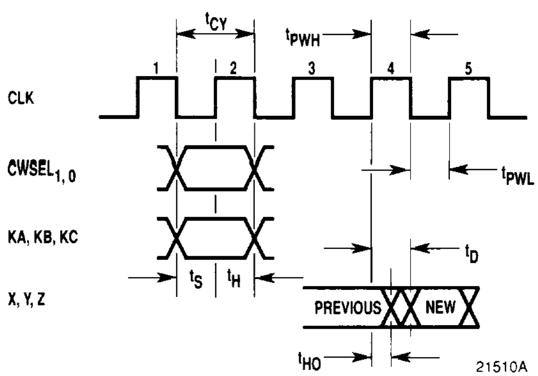
### Figure 2. Impulse Response




### Figure 3. Input/Output Timing Diagram



## Numeric Format and Overflow

*Table 2* shows the binary weightings of the input and output ports of the TMC2272. Although the internal sums of products could grow to 23-bits, the outputs X, Y, and Z are rounded to yield 12-bit integer words. Thus the output format is identical to the input data format. Bit weighting is easily adjusted by applying the same scaling correction factor to both input and output data words.

As shown in *Table 2*, the TMC2272's matched input and output data formats accommodate 0dB (unity) gain. Therefore the user must be aware of input conditions that could lead to numeric overflow. Maximum input data and coefficient word sizes must be taken into account with the specific translation performed to ensure that no overflow occurs.

## Use with Fewer Than 12 Bits

The TMC2272 can be configured to provide several format and overflow options when used in systems with fewer than 12-bits of resolution. An 8-bit system will be used as an example, however these concepts apply to any other word width.

The most apparent mode of operation is to left justify the incoming data and to ground the unused input LSBs. However, the outputs will still be rounded to the least significant bit of the TMC2272, having little if any effect on the top 8 bits actually used. Because the TMC2272 carries out all calculations to full precision, the preferred mode of operation is to right justify and sign extend the data as shown in *Figure 4*. Since all the LSBs are used, the desired output will be rounded correctly, and overflow will be accommodated by bits 7 through 10.

The TMC2272 may also be used in unsigned binary 8-bit systems as shown in *Figure 5*. Bits 11 through 8 will handle overflow.

In all applications, a digital zero (ground) should be connected to all unused inputs.

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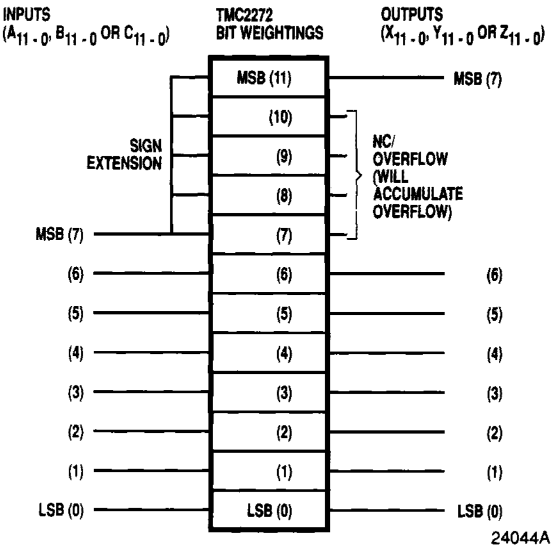
**Table 2. Bit Weightings for Input and Output Data Words**

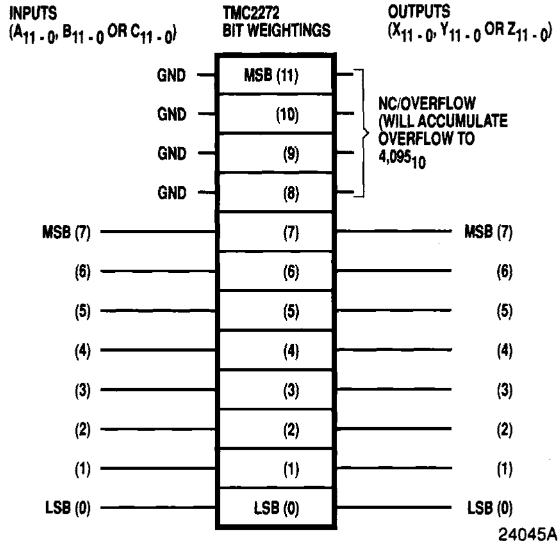
| Bit Weights | $2^{11}$ | $2^{10}$ | $2^{9}$ | $2^{8}$ | $2^{7}$ | $2^{6}$ | $2^{5}$ | $2^{4}$ | $2^{3}$ | $2^{2}$ | $2^{1}$ | $2^{0}$ | . | $2^{-1}$ | $2^{-2}$ | $2^{-3}$ | $2^{-4}$ | $2^{-5}$ | $2^{-6}$ | $2^{-7}$ | $2^{-8}$ | $2^{-9}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **INPUTS** | | | | | | | | | | | | | | | | | | | | | | |
| All Modes Data A, B, C | $-I_{11}$ | $I_{10}$ | $I_9$ | $I_8$ | $I_7$ | $I_6$ | $I_5$ | $I_4$ | $I_3$ | $I_2$ | $I_1$ | $I_0$ | . | | | | | | | | | |
| Coefficients KA, KB, KC | | | | | | | | | | | | $-K_9$ | . | $K_8$ | $K_7$ | $K_6$ | $K_5$ | $K_4$ | $K_3$ | $K_2$ | $K_1$ | $K_0$ |
| Internal Sum | $X_{20}$ | $X_{19}$ | $X_{18}$ | $X_{17}$ | $X_{16}$ | $X_{15}$ | $X_{14}$ | $X_{13}$ | $X_{12}$ | $X_{11}$ | $X_{10}$ | $X_9$ | . | $X_8$ | $X_7$ | $X_6$ | $X_5$ | $X_4$ | $X_3$ | $X_2$ | $X_1$ | $X_0$ |
| **OUTPUTS** | | | | | | | | | | | | | | | | | | | | | | |
| X, Y, Z | $-O_{11}$ | $O_{10}$ | $O_9$ | $O_8$ | $O_7$ | $O_6$ | $O_5$ | $O_4$ | $O_3$ | $O_2$ | $O_1$ | $O_0$ | . | | | | | | | | | |

Note: A minus sign indicates a two's complement sign bit.

## Figure 4. Two's Complement 8-Bit Application




## Figure 5. Binary 8-Bit Application




## **Absolute maximum ratings** (beyond which the device may be damaged)[1]

| | |
|---|---|
| **Supply Voltage** | –0.5 to +7.0V |
| **Input Voltage** | –0.5 to ($V_{DD}$ + 0.5)V |
| **Output** | |
| Applied voltage | –0.5 to ($V_{DD}$ + 0.5)V[2] |
| Forced current | –6.0 to 6.0mA[3,4] |
| Short-circuit duration (single output in HIGH state to ground) | 1 sec |
| **Temperature** | |
| Operating case | –60 to +130°C |
| junction | 175°C |
| Lead soldering (10 seconds) | 300°C |
| **Storage** | –65 to 150°C |

Notes:
1. Absolute maximum ratings are limiting values applied individually while all other parameters are within specified operating conditions. Functional operation under any of these conditions is NOT implied.
2. Applied voltage must be current limited to specified range, and measured with respect to GND.
3. Forcing voltage must be limited to specified range.
4. Current is specified as conventional current flowing into the device.

## Operating conditions

| Parameter | | Temperature Range Standard Min | Nom | Max | Units |
|---|---|---|---|---|---|
| $V_{DD}$ | Supply Voltage | 4.75 | 5.0 | 5.25 | V |
| $V_{IL}$ | Input Voltage,Logic LOW | | | 0.8 | V |
| $V_{IH}$ | Input Voltage,Logic HIGH | 2.0 | | | V |
| $I_{OL}$ | Output Current,Logic LOW | | | 4.0 | mA |
| $I_{OH}$ | Output Current,Logic HIGH | | | −2.0 | mA |
| $t_{CY}$ | Cycle Time | | | | |
| | TMC2272 | 33 | | | ns |
| | TMC2272-1 | 27.7 | | | ns |
| | TMC2272-2 | 25 | | | ns |
| $t_{PWL}$ | Clock Pulse Width,LOW | | | | |
| | TMC2272 | 15 | | | ns |
| | TMC2272-1 | 12 | | | ns |
| | TMC2272-2 | 10 | | | ns |
| $t_{PWH}$ | Clock Pulse Width,HIGH | 10 | | | ns |
| $t_S$ | Input Setup Time | | | | |
| | TMC2272 | 8 | | | ns |
| | TMC2272-1 | 7 | | | ns |
| | TMC2272-2 | 6 | | | ns |
| $t_H$ | Input Hold Time | | | | |
| | TMC2272 | 3 | | | ns |
| | TMC2272-1 | 3 | | | ns |
| | TMC2272-2 | 2 | | | ns |
| $T_A$ | Ambient Temperature, Still Air | 0 | | 70 | °C |

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## Electrical characteristics within specified operating conditions[1]

| Parameter | | Test Conditions | Temperature Range Standard Min | Max | Units |
|---|---|---|---|---|---|
| $I_{DDQ}$ | Supply Current, Quiescent | $V_{DD}$=Max, $V_{IN}$=0V | | 12 | mA |
| $I_{DDU}$ | Supply Current, Unloaded | $V_{DD}$=Max, f=20MHz | | 160 | mA |
| $I_{IL}$ | Input Current,Logic LOW[2] | $V_{DD}$=Max, $V_{IN}$=0V | | –10 | uA |
| $I_{IH}$ | Input Current,Logic HIGH[2] | $V_{DD}$=Max, $V_{IN}$=$V_{DD}$ | | 10 | uA |
| $I_{OIL}$ | Input Current,Logic LOW[3] | $V_{DD}$=Max, $V_{IN}$=0V | | –40 | uA |
| $I_{OIH}$ | Input Current,Logic HIGH[3] | $V_{DD}$=Max, $V_{IN}$=$V_{DD}$ | | 40 | uA |
| $V_{OL}$ | Output Voltage,Logic LOW | $V_{DD}$=Min, $I_{OL}$=4mA | | 0.4 | V |
| $V_{OH}$ | Output Voltage,Logic HIGH | $V_{DD}$=Min, $I_{OH}$=-2mA | 2.4 | | V |
| $I_{OS}$ | Short-Circuit Output Current | $V_{DD}$=Max, Output HIGH, One Pin to Ground, One Second Duration Max. | –20 | –80 | mA |
| $C_I$ | Input Capacitance | $T_A$=25°C, f=1MHz | | 10 | pF |
| $C_O$ | Output Capacitance | $T_A$=25°C, f=1MHz | | 10 | pF |

Notes:
1. Actual test conditions may vary from those shown, but guarantee operation as specified.
2. Except pins $X_{11-0}$, $Y_{11-0}$
3. Pins $X_{11-0}$, $Y_{11-8}$ only.

## Switching characteristics within specified operating conditions

| Parameter | | Test Conditions | Temperature Range Standard Min | Max | Units |
|---|---|---|---|---|---|
| $t_D$ | Output Delay | $V_{DD}$=Min, $C_{LOAD}$=25pF | | | |
| | TMC2272 | | | 18 | ns |
| | TMC2272-1 | | | 17 | ns |
| | TMC2272-2 | | | 16 | ns |
| $t_{HO}$ | Output Hold Time | $V_{DD}$=Max, $C_{LOAD}$=25pF | | | |
| | TMC2272 | | 4 | | ns |
| | TMC2272-1 | | 3 | | ns |
| | TMC2272-2 | | 3 | | ns |

**Figure 6. Equivalent Input Circuit**

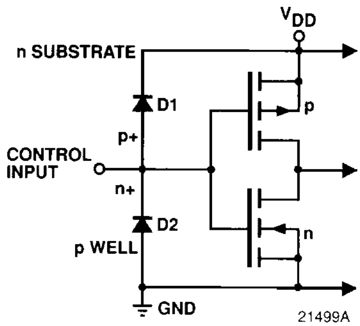
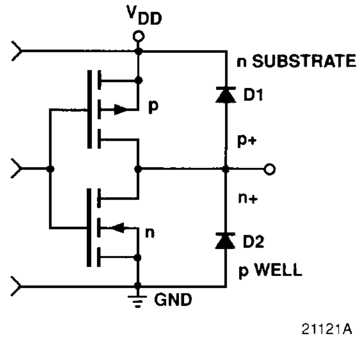



**Figure 7. Equivalent Output Circuit**




## Applications Discussion

The TMC2272 can convert between any two three-coordinate colorspaces with the selection of the proper coefficients. Sets of coefficients for some popular colorspace conversions are presented below.

By concatenating coefficient matrices of single transformations, the user can program the TMC2272 to perform compound transforms efficiently. For example, given an RGB input, correction of the relative values of R and B, for color temperature, conversion to YIQ, modification of contrast by changing Y, and conversion back to RGB can be performed as quickly and easily as any simple transformation. To calculate the final set of coefficients from the coefficients of the individual transformations, the procedure in *Figure 8* (concatenation) is used. If more than two matrices are to be combined, the result from the concatenation of the first two matrices is concatenated with the third. If more matrices must be incorporated in the final function, the last step is repeated.

**Figure 8. Concatenation**

$$\begin{vmatrix} A & B & C \\ D & E & F \\ G & H & I \end{vmatrix} \begin{vmatrix} J & K & L \\ M & N & O \\ P & Q & R \end{vmatrix} = \begin{vmatrix} AJ+BM+CP & AK+BN+CQ & AL+BO+CR \\ DJ+EM+FP & DK+EN+FQ & DL+EO+FR \\ GJ+HM+IP & GK+HN+IQ & GL+HO+IR \end{vmatrix}$$

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## Converting Video Data from RGB to YIQ or YUV

The TMC2272 simplifies the task of converting encoded color video data between the RGB (color component) format and the YIQ (quadrature encoded chrominance) or YUV (color difference) format. Beginning with RGB component data, the standard relationships, with 8-bit quantization, are:

$$Y = (77R + 150G + 29B)/256$$
$$I = (153R - 71G - 82B)/256 + 128$$
$$Q = (54R - 134G + 80B)/256 + 128$$

and

$$Y = (77R + 150G + 29B)/256$$
$$U = (131R - 110G - 21B)/256 + 128$$
$$V = (-44R - 87G + 131B)/256 + 128$$

In digital systems, I and Q or U and V are sometimes renormalized to:

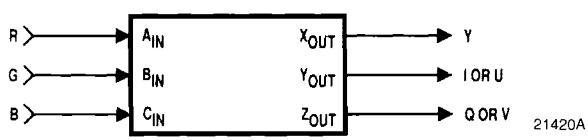
$$I = (128R - 59G - 69B)/256$$
$$Q = (52R - 128G + 76B)/256$$
$$U = (128R - 107G - 21B)/256$$
$$V = (-43R - 85G + 128B)/256$$

With each coefficient expressed as a fraction of 256, these numbers are easily converted to binary for loading into the coefficient storage of the TMC2272. The half-scale (80hex) offsets included in the chrominance and color-difference terms can easily be added to the appropriate sums after the matrix multiplication, if desired. *Table 3* contains the 10-bit two's complement coefficients to be loaded into the TMC2272 to perform the desired conversion from RGB format. Once these factors are in place the user can continuously convert encoded data at real-time video rates, with three new encoded outputs available on every clock cycle.

### Table 3. Colorspace Conversion Coefficients[1,2]

| Conversion | KAX | KAY | KAZ | KBX | KBY | KBZ | KCX | KCY | KCZ |
|---|---|---|---|---|---|---|---|---|---|
| RGB to YIQ | 04D | 099 | 036 | 096 | 3B9 | 37A | 01D | 3AE | 050 |
| RGB to YIQ[3] | 04D | 080 | 034 | 096 | 3C5 | 380 | 01D | 3BB | 04C |
| RGB to YUV | 04D | 083 | 3D4 | 096 | 392 | 3A9 | 01D | 3EB | 083 |
| RGB to YUV[3] | 04D | 080 | 3D5 | 096 | 395 | 3AB | 01D | 3EB | 080 |

Notes:
1. All entries are given in 10-bit two's complement hexadecimal such that all entries beginning in "2" or "3" are negative.
2. This table assumes the following bus assignments




3. Second and fourth rows are renormalized such that largest coefficient = .5 ($080_{hex}$)

## Converting Video Data from YIQ or YUV to RGB

With a different set of coefficients, the TMC2272 can perform the inverse conversions, whose governing equations are:

$$R = (256Y + 243I + 159Q)/256 \quad \text{and} \quad R = (256Y + 0U + 292V)/256$$
$$G = (256Y - 72I - 164Q)/256 \qquad\qquad G = (256Y - 101U - 149V)/256$$
$$B = (256Y - 284I + 443Q)/256 \qquad\qquad B = (256Y + 520U + 0V)/256$$

Since the first YUV —> RGB equation set includes the coefficient "520," which won't fit into a 10-bit two's complement integer format, we must either divide all coefficients by 2, degrading precision by one bit, or by 520/511. In *Table 4*, the 520/511 correction factor was selected.

The values corresponding to digital normalization (see RGB to YIQ discussion) are:

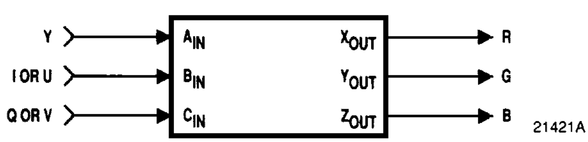
$$R = 256Y + 292I + 167Q)/256 \quad \text{and} \quad R = (256Y + 0U + 359V)/256$$
$$G = (256Y - 86I - 172Q)/256 \qquad\qquad G = (256Y - 88U - 183V)/256$$
$$B = (256I - 341I + 456Q)/256 \qquad\qquad B = (256Y + 453U + 0V)/256$$

### Table 4. Colorspace Conversion Coefficients[1,2]

| Conversion | KAX | KAY | KAZ | KBX | KBY | KBZ | KCX | KCY | KCZ |
|---|---|---|---|---|---|---|---|---|---|
| YIQ to RGB | 100 | 100 | 100 | 0F3 | 3B8 | 3E4 | 09F | 35C | 1BB |
| YIQ to RGB[3] | 100 | 100 | 100 | 124 | 3AA | 2AB | 0A7 | 354 | 101 |
| YUV to RGB | 0FC | 0FC | 0FC | 000 | 39D | 1FF | 11F | 36E | 000 |
| YUV to RGB[3] | 100 | 100 | 100 | 000 | 3A8 | 125 | 167 | 349 | 000 |

Notes:

1. All entries are given in 10-bit two's complement hex, such that all entries beginning in "2" or "3" are negative.
2. This table assumes the following bus assignments:




3. Second and fourth rows are renormalized such that largest coefficient = .5 ($080_{hex}$).

## HSV (HSI) Format Conversions

HSV (or HSI) refers to Hue (color) Saturation (vividness) and Value (intensity or brightness), quantities which are directly related to the human perception of light and color. The V (or I) levels are simply the Y (or luminance) levels. Hue and Saturation are derived from the R-Y and B-Y color difference values of a signal.

HSV Calculations:

Value (V) = Intensity (I) = Y

Hue (H) = Arctan (B-Y/R-Y)

Saturation (S) = $\sqrt{(R\text{-}Y)^2 + (B\text{-}Y)^2}$

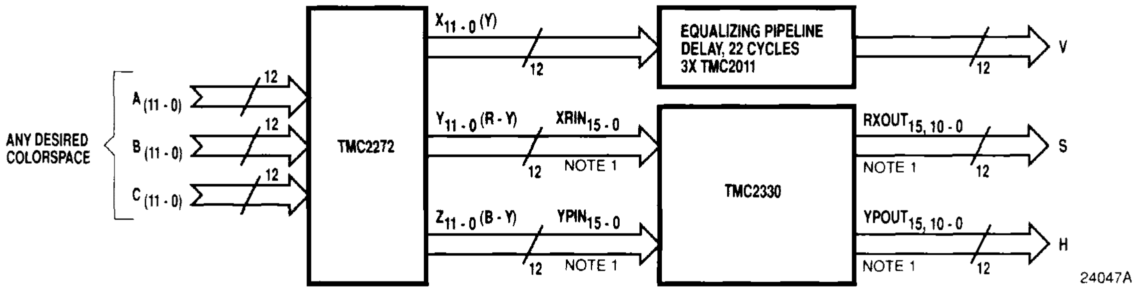
R-Y = S * cos(H)

B-Y = S * sin(H)

One may use two 64Kx8 ROM look-up-tables to calculate Hue and Saturation from R-Y and B-Y in an 8-bit system. However, the finite size of this LUT may limit performance, especially if the TMC2272's full precision is used. The TMC2330, developed to translate between rectangular and polar coordinates, can perform the trigonometric transformations to 16 bit precision at 25MHz. These calculations are the the same as required in HSV calculations. A 4 Giga-byte x 32 bit LUT can achieve the same accuracy and precision as the TMC2330, if it is programmed correctly.

To convert between Y, R-Y, B-Y and HSV, the the TMC2272 isn't needed at all; simply use the TMC2330. To convert between HSV and any other format, use the TMC2330 to translate between HSV and Y, R-Y, B-Y, and use the TMC2272 to translate between Y, R-Y, B-Y and the other format. See *Figures 9* and *10*.

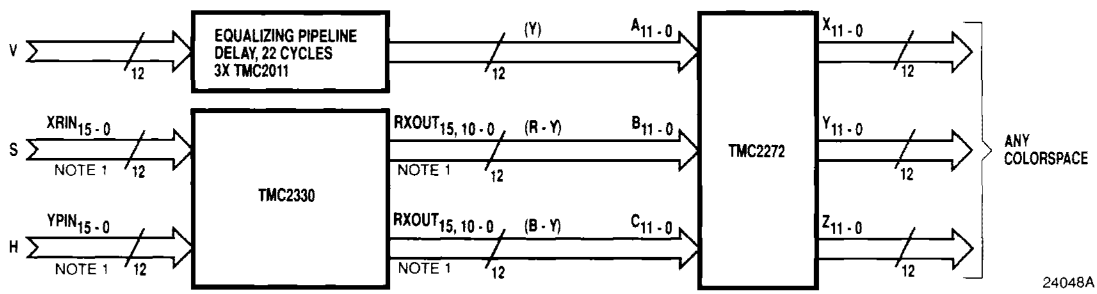
### Figure 9. Conversion to HSV




Notes: 1. Connect TMC2272 MSBs (Bits 11) to TMC 2330 MSBs (Bits 15) and also to TMC2330 Bits 14-11. Connect TMC2272 LSBs (Bits 10-0) to TMC2330 LSBs (Bits 10-0). TMC2330 output bits 14-11 are overflow.

2. TMC2272 $Y_{11-0}$ outputs should not be confused with the designation "Y" used to signify the intensity components. The assignment of components to TMC2272 inputs and outputs may be altered through the selection of appropriate coefficients.

### Figure 10. Conversion from HSV




Notes: 1. Connect input MSBs (Bits 11) to TMC2330 MSBs (Bits 15( and also to TMC2330 Bits 14-11 Connect input LSBs (Bits 10-0) to TMC2330 LSBs (Bits 10-0).

2. TMC2272 $Y_{11-0}$ outputs should not be confused with the designation 'Y' used for an intensity component. Component assignment depends on the coefficients used.

## Input Interpolation/Output Decimation and Filtering

In some applications the two color-difference signals (R-Y/B-Y or Cr/Cb, for example,) are transmitted at one-half the rate of the luminance (Y) signal. These two color-difference signals are often multiplexed to one signal which is at the same sample rate as the luminance signal. In many applications, if the color difference signals are already band-limited, it is satisfactory to use the same color difference sample for each two luminance samples. Little improvement is obtained with a simple averaging ([A+B]/2) interpolation filter. If the color difference signal is not band-limited, either of these two methods may yield unsatisfactory results due to aliasing. In this case, a TRW TMC2242 digital low-pass ("half-band") interpolating filter will correctly band-limit each color difference signal as it is interpolated. See *Figure 11.*

The same methods are used to decimate the color difference outputs. Simple decimation by removing every other sample of color information may yield unsatisfactory results due to aliasing. This is a problem because the color difference signals have now been transformed with the higher-bandwidth luminance signals and therefore have higher bandwidths than they had before the transform. The best performance is obtained by using a precise low-pass ("half-band") decimation filter such as the TRW TDC2242 to remove aliasing components. See *Figure 12.*

The TDC2242 is a bi-directional, selectable rate filter/ interpolator/decimator.

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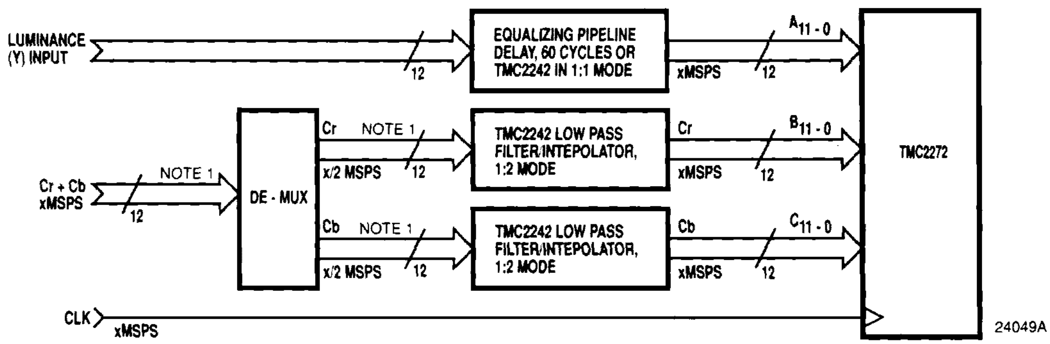
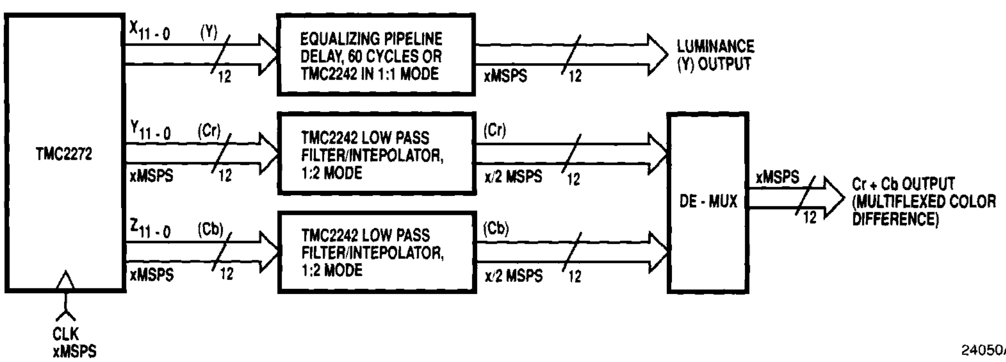
**Figure 11. Input Interpolation and Filtering**




Notes: 1. Width of input paths will vary with source.
2. See TMC2242 Datasheet for further information.

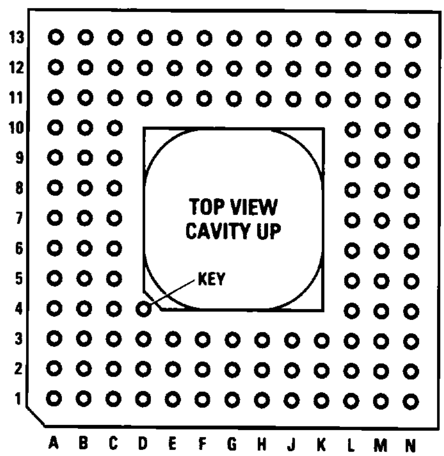
**Figure 12. Output Decimation and Filtering**



**Pin Assignments** – 121-Pin Plastic Pin Grid Array H5 Package

| Pin | Name | Pin | Name | Pin | Name | Pin | Name | Pin | Name | Pin | Name | Pin | Name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | X7 | B5 | GND | C9 | $C_0$ | F1 | $Y_7$ | H13 | $A_1$ | L5 | $KC_0$ | M9 | $KB_2$ |
| A2 | $X_9$ | B6 | $C_9$ | C10 | $B_8$ | F2 | $Y_8$ | J1 | $Y_1$ | L6 | GND | M10 | $KB_5$ |
| A3 | $X_{10}$ | B7 | $C_6$ | C11 | $B_5$ | F3 | $V_{DD}$ | J2 | $Y_2$ | L7 | $V_{DD}$ | M11 | $KB_9$ |
| A4 | GND | B8 | $C_4$ | C12 | $B_3$ | F11 | $A_7$ | J3 | GND | L8 | $KB_0$ | M12 | $KA_2$ |
| A5 | $C_{11}$ | B9 | $C_2$ | C13 | $B_1$ | F12 | $A_6$ | J11 | $KA_8$ | L9 | $KB_4$ | M13 | $KA_3$ |
| A6 | $C_8$ | B10 | $B_{11}$ | D1 | $Y_{11}$ | F13 | $A_5$ | J12 | $CWSEL_1$ | L10 | $KB_8$ | N1 | $Z_5$ |
| A7 | $C_7$ | B11 | $B_9$ | D2 | $X_0$ | G1 | $Y_5$ | J13 | $CWSEL_0$ | L11 | $KA_1$ | N2 | $Z_8$ |
| A8 | $C_5$ | B12 | $B_6$ | D3 | $X_3$ | G2 | $Y_6$ | K1 | $Y_3$ | L12 | $KA_5$ | N3 | $Z_{10}$ |
| A9 | $C_3$ | B13 | $B_2$ | D11 | CLK | G3 | GND | K2 | $Z_0$ | L13 | $KA_6$ | N4 | $KC_1$ |
| A10 | $C_1$ | C1 | $X_1$ | D12 | $B_0$ | G11 | $A_3$ | K3 | $Z_3$ | M1 | $Z_2$ | N5 | $KC_3$ |
| A11 | $B_{10}$ | C2 | $X_2$ | D13 | $A_{10}$ | G12 | $A_2$ | K11 | $KA_4$ | M2 | $Z_7$ | N6 | $KC_5$ |
| A12 | $B_7$ | C3 | $X_6$ | E1 | $Y_9$ | G13 | $A_4$ | K12 | $KA_7$ | M3 | $Z_9$ | N7 | $KC_7$ |
| A13 | $B_4$ | C4 | $V_{DD}$ | E2 | $Y_{10}$ | H1 | $Y_4$ | K13 | $KA_9$ | M4 | $Z_{11}$ | N8 | $KC_8$ |
| B1 | $X_4$ | C5 | GND | E3 | GND | H2 | $Y_0$ | L1 | $Z_1$ | M5 | $KC_2$ | N9 | $KB_1$ |
| B2 | $X_5$ | C6 | $C_{10}$ | E11 | $A_{11}$ | H3 | $V_{DD}$ | L2 | $Z_4$ | M6 | $KC_4$ | N10 | $KB_3$ |
| B3 | $X_8$ | C7 | GND | E12 | $A_9$ | H11 | GND | L3 | $Z_6$ | M7 | $KC_6$ | N11 | $KB_6$ |
| B4 | $X_{11}$ | C8 | $V_{DD}$ | E13 | $A_8$ | H12 | $A_0$ | L4 | GND | M8 | $KC_9$ | N12 | $KB_7$ |
| | | | | | | | | | | | | N13 | $KA_0$ |

Note: Pin D4 has no electrical connection. It is a mechanical orientation pin.

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## Ordering Information

| Product Number | Speed MHz | Temperature Range | Screening | Package | Package Marking |
|---|---|---|---|---|---|
| TMC2272H5C | 30 | STD-TA = 0°C to 70°C | Commercial | 121 Pin Plastic PGA | 2272H5C |
| TMC2272H5C-1 | 36 | STD-TA = 0°C to 70°C | Commercial | 121 Pin Plastic PGA | 2272H5C-1 |
| TMC2272H5C-2 | 40 | STD-$T_A$ = 0°C to 70°C | Commercial | 121 Pin Plastic PGA | 2272H5C-2 |

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