Advance Information

Low Voltage PLL Clock Driver

MPC972
MPC973

LOW VOLTAGE PLL CLOCK DRIVER

The MPC972/973 are 3.3V compatible, PLL based clock driver devices targeted for high performance CISC or RISC processor based systems. With output frequencies of up to 200MHz and skews of 350ps the MPC972/973 are ideally suited for the most demanding synchronous systems. The devices offer twelve low skew outputs plus a feedback and sync output for added flexibility and ease of system implementation.

- Fully Integrated PLL
- Output Frequency up to 200MHz
- Compatible with PowerPC™ and Pentium™ Microprocessors
- TQFP Packaging
- 3.3V V_{CC}
- ± 50ps Typical Cycle–to–Cycle Jitter

FA SUFFIX
TQFP PACKAGE
CASE 848D-02

The MPC972/973 features an extensive level of frequency programmability between the 12 outputs as well as the input vs output relationships. Using the select lines output frequency ratios of 1:1, 2:1, 3:1, 3:2, 4:1, 4:3, 5:1, 5:2, 5:3, 6:1 and 6:5 between outputs can be realized by pulsing low one clock edge prior to the coincident edges of the Qa and Qc outputs. The Sync output will indicate when the coincident rising edges of the above relationships will occur. The selectability of the feedback frequency is independent of the output frequencies, this allows for very flexible programming of the input reference vs output frequency relationship. The output frequencies can be either odd or even multiples of the input reference. In addition the output frequency can be less than the input frequency for applications where a frequency needs to be reduced by a non–binary factor. Note that the device cannot dynamically switch between frequency selections. The device must be reset (with either the Power–On Reset or the $\overline{\text{MR/Tristate}}$ input) after the frequency select pins are asserted. The Power–On Reset ensures proper programming if the frequency select pins are set at power up.

The MPC972/973 offers a very flexible output enable/disable scheme. This enable/disable scheme helps facilitate system debug as well as provide unique opportunities for system power down schemes to meet the requirements of “green” class machines. The MPC972 allows for the enabling of each output independently via a serial input port. When disabled or “frozen” the outputs will be locked in the “LOW” state, however the internal state machines will continue to run. Therefore when “unfrozen” the outputs will activate synchronous and in phase with those outputs which were not frozen. The freezing and unfreezing of outputs occurs only when they are already in the “LOW” state, thus the possibility of runt pulse generation is eliminated. A power-on reset will ensure that upon power up all of the outputs will be active. Note that all of the control inputs on the MPC972/973 have internal pull–up resistors.

The MPC972/973 is fully 3.3V compatible and requires no external loop filter components. All inputs accept LVCMOS/LVTTL compatible levels while the outputs provide LVCMOS levels with the capability to drive 50Ω transmission lines. For series terminated lines each MPC972/973 output can drive two 50Ω lines in parallel thus effectively doubling the fanout of the device.

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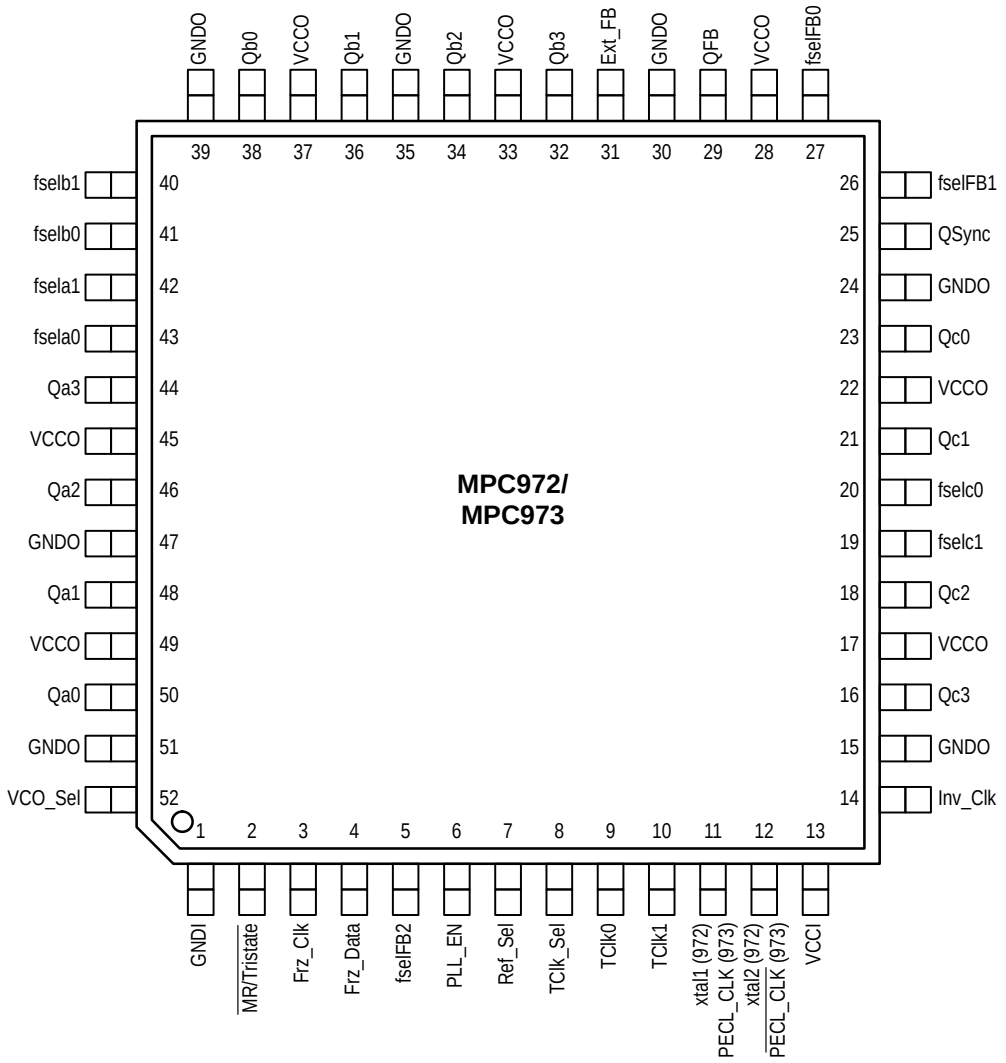
This document contains information on a new product. Specifications and information herein are subject to change without notice.



FUNCTION TABLE 1

fsela1	fsela0	Qa	fselb1	fselb0	Qb	fselc1	fselc0	Qc
0	0	÷4	0	0	÷4	0	0	÷2
0	1	÷6	0	1	÷6	0	1	÷4
1	0	÷8	1	0	÷8	1	0	÷6
1	1	÷12	1	1	÷10	1	1	÷8

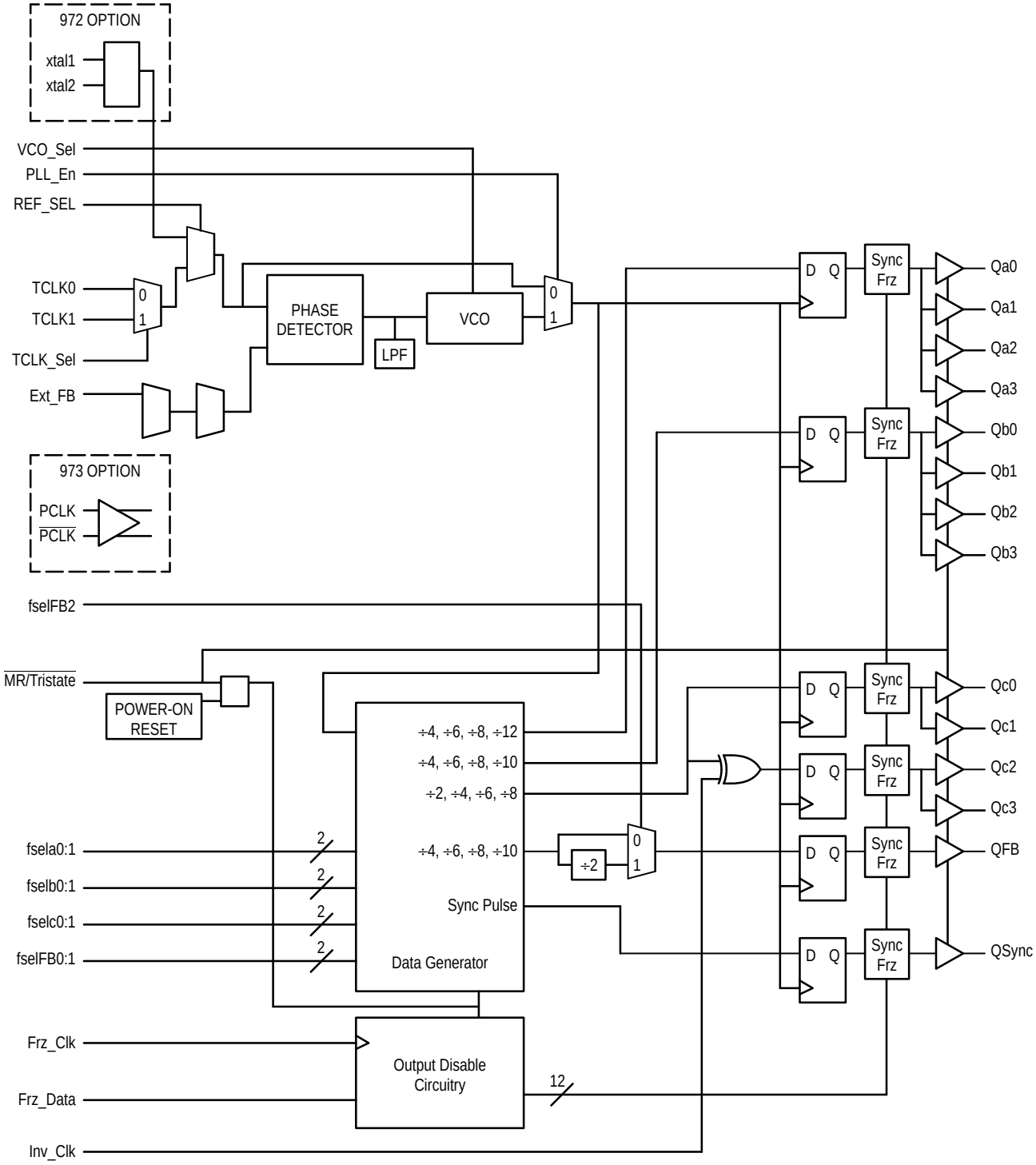
FUNCTION TABLE 2

fselFB2	fselFB1	fselFB0	QFB
0	0	0	÷4
0	0	1	÷6
0	1	0	÷8
0	1	1	÷10
1	0	0	÷8
1	0	1	÷12
1	1	0	÷16
1	1	1	÷20

FUNCTION TABLE 3

Control Pin	Logic ‘0’	Logic ‘1’
VCO_Sel	VCO/2	VCO
Ref_Sel	TCLK	Xtal (PECL)
TCLK_Sel	TCLK0	TCLK1
PLL_En	Bypass PLL	Enable PLL
$\overline{\text{MR/Tristate}}$	Master Reset/Output Tristate	Enable Outputs
Inv_Clk	Non–Inverted Qc2, Qc3	Inverted Qc2, Qc3

LOGIC DIAGRAM



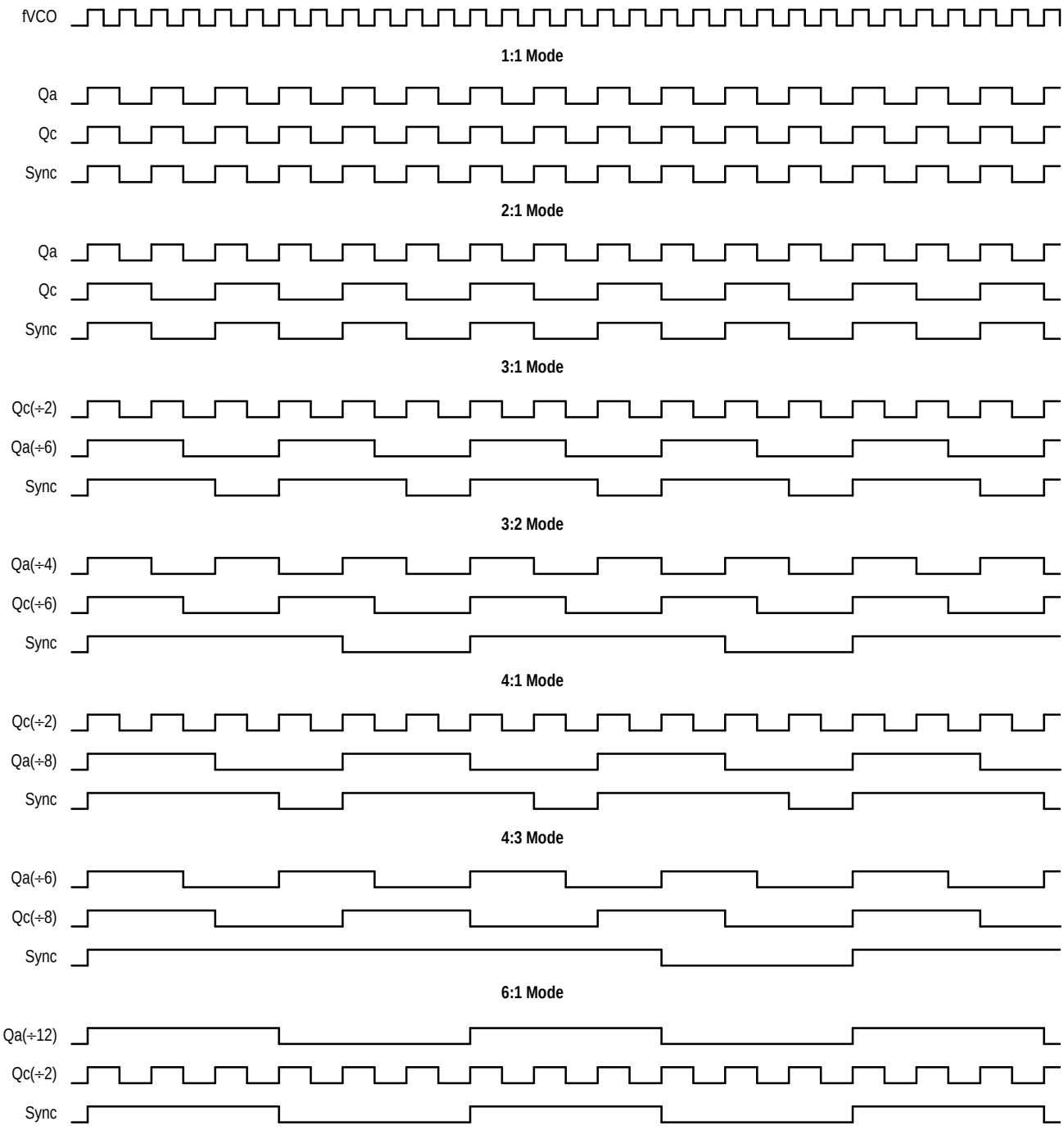


Figure 1. Timing Diagrams

ABSOLUTE MAXIMUM RATINGS*

Symbol	Parameter	Min	Max	Unit
V_{CC}	Supply Voltage	–0.3	4.6	V
V_I	Input Voltage	–0.3	V_{DD} + 0.3	V
I_{IN}	Input Current	TBD	TBD	mA
T_{Stor}	Storage Temperature Range	–40	125	°C

* Absolute maximum continuous ratings are those values beyond which damage to the device may occur. Exposure to these conditions or conditions beyond those indicated may adversely affect device reliability. Functional operation under absolute-maximum-rated conditions is not implied.

DC CHARACTERISTICS (T_A = 0° to 70°C, V_{CC} = 3.3V ±0.3V)

Symbol	Characteristic	Min	Typ	Max	Unit	Condition
V_{IH}	Input HIGH Voltage	2.0		3.6	V	
V_{IL}	Input LOW Voltage	0.8			V	
V_{OH}	Output HIGH Voltage	2.4			V	I_{OH} = –20mA**1**
V_{OL}	Output LOW Voltage			0.5	V	I_{OL} = 20mA**1**
I_{IN}	Input Current			±100	µA	
I_{CC}	Maximum Quiescent Supply Current			TBD	mA	
C_{IN}	Input Capacitance			4	pF	
C_{pd}	Power Dissipation Capacitance				pF	

1 The MPC972/973 outputs can drive series or parallel terminated 50Ω (or 50Ω to V_{CC}/2) transmission lines on the incident edge (see Applications Info section).

2 Inputs have pull–up resistors which affect input current, $\overline{\text{PECL\_CLK}}$ has a pull–down resistor.

PLL INPUT REFERENCE CHARACTERISTICS (T_A = 0 to 70°C)

Symbol	Characteristic	Min	Max	Unit	Condition
t_r, t_f	TCLK Input Rise/Falls		3.0	ns	
f_{ref}	Reference Input Frequency	10	Note 1	MHz	
f_{refDC}	Reference Input Duty Cycle	25	75	%	

1 Maximum input reference frequency is limited by the VCO lock range and the feedback divider.

AC CHARACTERISTICS (T_A = 0° to 70°C, V_{CC} = 3.3V ±0.3V)

Symbol	Characteristic		Min	Typ	Max	Unit	Condition
t_r, t_f	Output Rise/Fall Time		0.15		1.5	ns	0.8 to 2.0V
t_{pw}	Output Duty Cycle			$t_{CYCLE}/2$ ±500		ps	
t_{Xtal}	Crystal Oscillator Frequency		10		25	MHz	Note 3
t_{pd}	SYNC to Feedback Propagation Delay	Feedback = VCO/4	TBD	X_1±150	TBD	ps	Note 1
		Feedback = VCO/6		X_2±150			
		Feedback = VCO/8		X_3±150			
		Feedback = VCO/10		X_4±150			
		Feedback = VCO/12		X_5±150			
		Feedback = VCO/16		X_6±150			
		Feedback = VCO/20		X_7±150			
t_{os}	Output-to-Output Skew	Same Frequency			350	ps	
		Different Frequency			500		
f_{VCO}	VCO Lock Range	Feedback = VCO/4	TBD	100–500	TBD	MHz	
		Feedback = VCO/6	TBD	100–500	TBD		
		Feedback = VCO/8	TBD	100–500	TBD		
		Feedback = VCO/10	TBD	100–500	TBD		
		Feedback = VCO/12	TBD	100–500	TBD		
		Feedback = VCO/16	TBD	100–500	TBD		
		Feedback = VCO/20	TBD	100–500	TBD		
f_{max}	Maximum Output Frequency	Q (÷2)			200	MHz	
		Q (÷4)			125		
		Q (÷6)			83.33		
		Q (÷8)			62.5		
t_{jitter}	Cycle–to–Cycle Jitter (Peak–to–Peak)			±50	±100	ps	
t_{lock}	Maximum PLL Lock Time				10	ms	
t_s	Setup Time	fsel to $\overline{MR/Tristate}$					Note 2

1 X_1, X_2, X_3, X_4, X_5, X_6, and X_7 all to be determined. The specs hold only when the 972 or 973 is used in the external feedback mode.
2 The amount of time after a change in the fequency divide select the $\overline{MR/Tristate}$ must be held “low”.
3 See Applications Info section for more crystal information.

APPLICATIONS INFORMATION

Programming the MPC972/973

The MPC972/973 is the most flexible frequency programming device in the Motorola timing solution portfolio. With three independent banks of four outputs as well as an independent PLL feedback output the total number of possible configurations is too numerous to tabulate. Table 1 tabulates the various selection possibilities for the three banks of outputs. The divide numbers presented in the table represent the divider applied to the output of the VCO for that bank of outputs. To determine the relationship between the three backs the three divide ratios would be compared. For instance if a frequency relationship of 5:3:2 was desired the following selection could be made. The Qb outputs could be set to ÷10, the Qa outputs to ÷6 and the Qc outputs to ÷4. With this output divide selection the desired 5:3:2 relationship would be generated. For situations where the VCO will run at relatively low frequencies the PLL may not be stable for the desired divide ratios. For these circumstances the VCO_Sel pin allows for an extra ÷2 to be added into the clock path. When asserted this pin will maintain the desired output relationships, but will provide an enhanced lock range for the PLL. Once the output frequency relationship is set and the VCO is in its stable range the feedback output would be programmed to match the input reference frequency.

The MPC972/973 offers only an external feedback to the PLL. A separate feedback output is provided to optimize the flexibility of the device. If in the example above the input reference frequency was equal to the lowest output frequency the feedback output would be set in the ÷10 mode. If the input needed to be half the lowest frequency output the fselFB2 input could be asserted to half the feedback frequency. This action multiplies the output frequencies by two relative to the input reference frequency. With 7 unique feedback divide capabilities there is a tremendous amount of flexibility. Again assume the above 5:3:2 relationship is needed with the highest frequency output equal to 100MHz. If one was also constrained because the only reference frequency available was 50MHz the setup in Figure 2 could be used. The MPC972/973 provides the 100, 66 and 40MHz outputs all synthesized from the 50MHz source. With its

multitude of divide ratio capabilities the MPC972/973 can generate almost any frequency from a standard, common frequency already present in a design. Figure 3 and Figure 4 illustrate a few more examples of possible MPC972/973 configurations.

The MPC972/973 has one more prgramming feature added to its arsenal. The Inv_Clk input pin when asserted will invert the Qc2 and Qc3 outputs. This inversion will not affect the output–output skew of the device. This inversion allows for the development of 180° phase shifted clocks. This output could also be used as a feedback output to the MPC972/973 or a second PLL device to generate early or late clocks for a specific design. Figure 5 illustrates the use of two MPC972/973's to generate two banks of clocks with one bank divided by 2 and delayed by 180° relative to the first.

Using the MPC973 as a Zero Delay Buffer

The external feedback of the MPC973 clock driver allows for its use as a zero delay buffer (if the TCLK inputs are used the MPC972 can also be used a zero delay buffer). By using one of the outputs as a feedback to the PLL the propagation delay through the device is eliminated. The PLL works to align the output edge with the input reference edge thus producing a near zero delay. The feedback divider affects the static phase offset of the PLL and thus the relative delay between the inputs and outputs. Because the static phase offset is a function of the feedback divisor the Tpd of the MPC973 is a function of the feedback configuration used. The Tpd of the device is specified in the specification tables.

When used as a zero delay buffer the MPC973 will likely be in a nested clock tree application. For these applications the MPC973 offers a LVPECL clock input as a PLL reference. This allows the user to use LVPECL as the primary clock distribution device to take advantage of its far superior skew performance. The MPC973 then can lock onto the LVPECL reference and translate with near zero delay to low skew LVCMOS outputs. Clock trees implemented in this fashion will show significantly tighter skews than trees developed from CMOS fanout buffers.

To minimize part–to–part skew the external feedback option again should be used. The PLL in the MPC973 decouples the delay of the device from the propagation delay variations of the internal gates. From the specification table one sees a Tpd variation of only ±150ps, thus for multiple devices under identical configurations the part–to–part skew will be around 650ps (300ps for Tpd variation plus 350ps output–to–output skew). For devices that are configured differently one must account for the differences between the nominal delays of the multiple devices.

SYNC Output Description

In situations where output frequency relationships are not integer multiples of each other there is a need for a signal for system synchronization purposes. The SYNC output of the MPC972/973 is designed to specifically address this need. The MPC972/973 monitors the relationship between the Qa and the Qc banks of outputs. It provides a low going pulse, one period in duration, one period prior to the coincident rising edges of the Qa and Qc outputs. The duration and the placement of the pulse is dependent on the higher of the Qa and Qc output frequencies. The timing diagrams in the data sheet show the various waveforms for the SYNC output. Note that the SYNC output is defined for all possible combinations of the Qa and Qc outputs even though under some relationships the lower frequency clock could be used as a synchronizing signal.

Table 1. Programmable Output Frequency Relationships (VCO_Sel='1')

fsela1	fsela0	Qa	fselb1	fselb0	Qb	fselc1	fselc0	Qc
0	0	VCO/4	0	0	VCO/4	0	0	VCO/2
0	1	VCO/6	0	1	VCO/6	0	1	VCO/4
1	0	VCO/8	1	0	VCO/8	1	0	VCO/6
1	1	VCO/12	1	1	VCO/10	1	1	VCO/8

Table 2. Programmable Output Frequency Relationships (VCO_Sel='1')

fselFB2	fselFB1	fselFB0	QFB
0	0	0	VCO/4
0	0	1	VCO/6
0	1	0	VCO/8
0	1	1	VCO/10
1	0	0	VCO/8
1	0	1	VCO/12
1	1	0	VCO/16
1	1	1	VCO/20

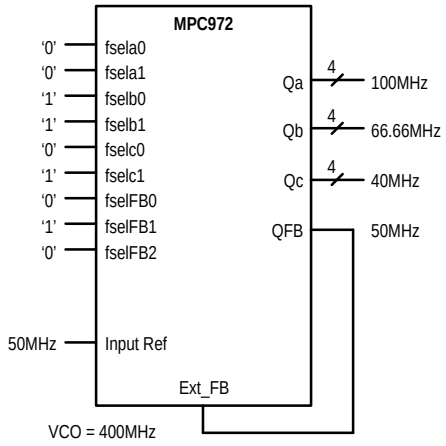


Figure 2. Programming Configuration Example

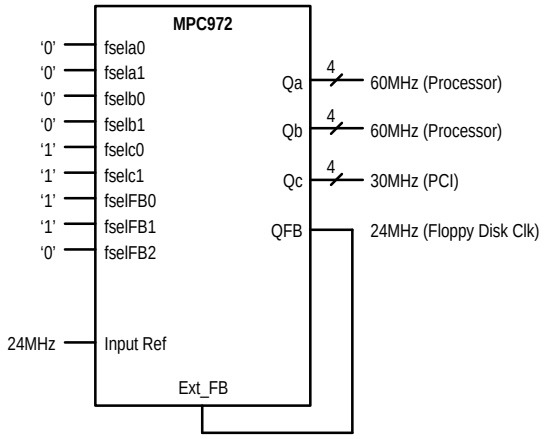


Figure 3. Generating Pentium Clocks from Floppy Clock

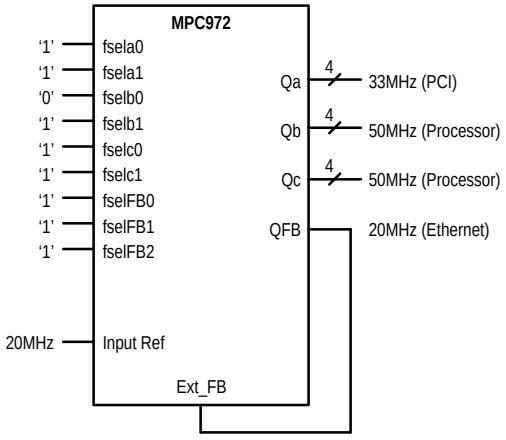


Figure 4. Generating MPC604 Clocks from Ethernet Clocks

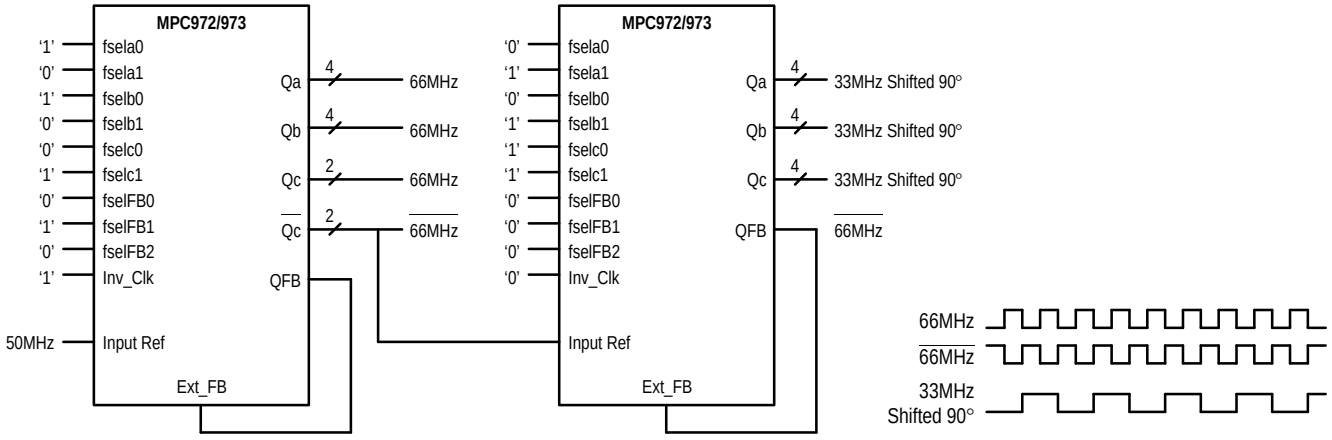


Figure 5. Phase Delay Using Multiple MPC972/973's

Using the On–Board Crystal Oscillator

The MPC972/973 features an on–board crystal oscillator to allow for seed clock generation as well as final distribution. The on–board oscillator is completely self contained so that the only external component required is the crystal. As the oscillator is somewhat sensitive to loading on its inputs the user is advised to mount the crystal as close to the MPC972/973 as possible to avoid any board level parasitics. To facilitate co–location surface mount crystals are recommended, but not required. In addition, with crystals with a higher shunt capacitance, it may be necessary to place a 1k resistor across the two crystal leads.

The oscillator circuit is a series resonant circuit as opposed to the more common parallel resonant circuit, this eliminates the need for large on–board capacitors. Because the design is a series resonant design for the optimum frequency accuracy a series resonant crystal should be used (see specification table below). Unfortunately most off the shelf crystals are characterized in a parallel resonant mode. However a parallel resonant crystal is physically no different than a series resonant crystal, a parallel resonant crystal is simply a crystal which has been characterized in its parallel resonant mode. Therefore in the majority of cases a parallel specified crystal can be used with the MPC972/973 with just a minor frequency error due to the actual series resonant frequency of the parallel resonant specified crystal. Typically a parallel specified crystal used in a series resonant mode will exhibit an oscillatory frequency a few hundred ppm lower than the specified value. For most processor implementations a few hundred ppm translates into kHz inaccuracies, a level which does not represent a major issue.

Table 3. Crystal Specifications

Parameter	Value
Crystal Cut	Fundamental AT Cut
Resonance	Series Resonance*
Frequency Tolerance	±75ppm at 25°C
Frequency/Temperature Stability	±150pm 0 to 70°C
Operating Range	0 to 70°C
Shunt Capacitance	5pF Max
Equivalent Series Resistance (ESR)	50 to 80Ω
Correlation Drive Level	100μW
Aging	5ppm/Yr (First 3 Years)

* See accompanying text for series versus parallel resonant discussion.

The MPC972/973 is a clock driver which was designed to generate outputs with programmable frequency relationships and not a synthesizer with a fixed input frequency. As a result the crystal input frequency is a function of the desired output frequency. For a design which utilizes the external feedback to the PLL the selection of the crystal frequency is straight forward; simply chose a crystal which is equal in frequency to the fed back signal.

Driving Transmission Lines

The MPC972/973 clock driver was designed to drive high speed signals in a terminated transmission line environment. To provide the optimum flexibility to the user the output drivers were designed to exhibit the lowest impedance possible. With an output impedance of less than 10Ω the drivers can drive either parallel or series terminated transmission lines. For more information on transmission lines the reader is referred to application note AN1091 in the Timing Solutions brochure (BR1333/D).

In most high performance clock networks point–to–point distribution of signals is the method of choice. In a point–to–point scheme either series terminated or parallel terminated transmission lines can be used. The parallel technique terminates the signal at the end of the line with a 50Ω resistance to VCC/2. This technique draws a fairly high level of DC current and thus only a single terminated line can be driven by each output of the MPC972/973 clock driver. For the series terminated case however there is no DC current draw, thus the outputs can drive multiple series terminated lines. Figure 6 illustrates an output driving a single series terminated line vs two series terminated lines in parallel. When taken to its extreme the fanout of the MPC972/973 clock driver is effectively doubled due to its capability to drive multiple lines.

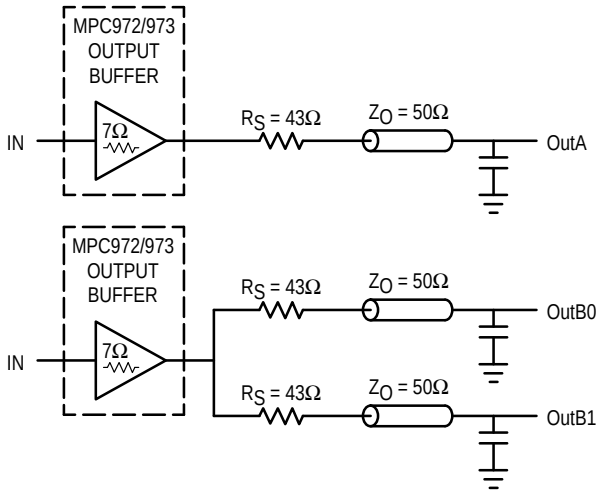


Figure 6. Single versus Dual Transmission Lines

The waveform plots of Figure 7 show the simulation results of an output driving a single line vs two lines. In both cases the drive capability of the MPC972/973 output buffers is more than sufficient to drive 50Ω transmission lines on the incident edge. Note from the delay measurements in the simulations a delta of only 43ps exists between the two differently loaded outputs. This suggests that the dual line driving need not be used exclusively to maintain the tight output–to–output skew of the MPC972/973. The output waveform in Figure 7 shows a step in the waveform, this step is caused by the impedance mismatch seen looking into the driver. The parallel combination of the 43Ω series resistor plus the output impedance does not match the parallel combination of the line impedances. The voltage wave launched down the two lines will equal:

VL = VS (Zo / Rs + Ro +Zo) = 3.0 (25/53.5) = 1.40V

At the load end the voltage will double, due to the near unity reflection coefficient, to 2.8V. It will then increment towards the quiescent 3.0V in steps separated by one round trip delay (in this case 4.0ns).

Since this step is well above the threshold region it will not cause any false clock triggering, however designers may be uncomfortable with unwanted reflections on the line. To better match the impedances when driving multiple lines the situation in Figure 8 should be used. In this case the series terminating resistors are reduced such that when the parallel combination is added to the output buffer impedance the line impedance is perfectly matched.

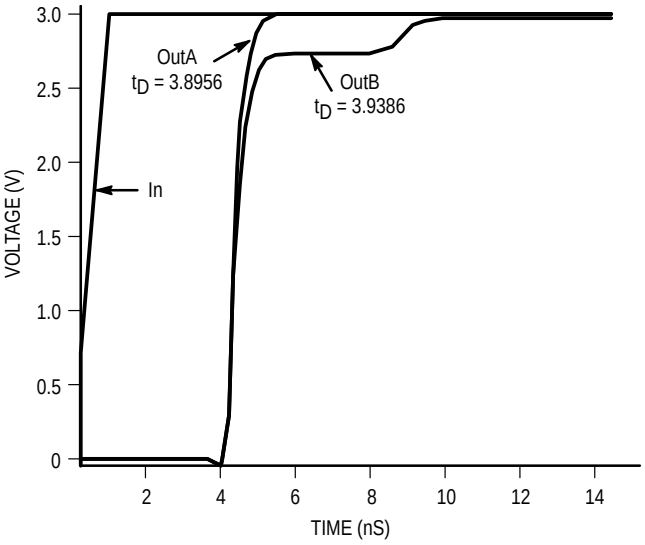
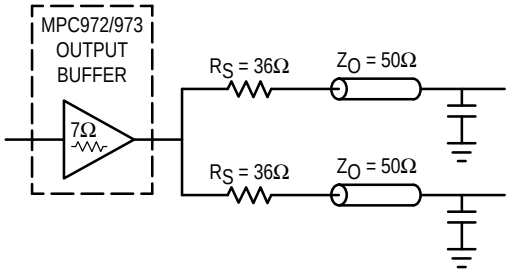


Figure 7. Single versus Dual Waveforms



7Ω + 36Ω || 36Ω = 50Ω || 50Ω
25Ω = 25Ω

Figure 8. Optimized Dual Line Termination

SPICE level output buffer models are available for engineers who want to simulate their specific interconnect schemes. In addition IV characteristics are in the process of being generated to support the other board level simulators in general use.

Using the Output Freeze Circuitry

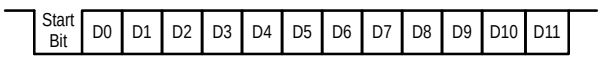
With the recent advent of a “green” classification for computers the desire for unique power management among system designers is keen. The individual output enable control of the MPC972/973 allows designers, under software control, to implement unique power management schemes into their designs. Although useful, individual output control at the expense of one pin per output is too high, therefore a simple serial interface was derived to economize on the control pins.

The freeze control logic provides a mechanism through which the MPC972 clock outputs may be frozen (stopped in the logic ‘0’ state):

The freeze mechanism allows serial loading of the 12–bit Serial Input Register, this register contains one program–mable freeze enable bit for 12 of the 14 output clocks. The Qc0 and QSync outputs cannot be frozen with the serial port, this avoids any potential lock up situation should an error occur in the loading of the Serial Input Register. The user may programmably freeze an output clock by writing logic ‘0’ to the respective freeze enable bit. Likewise, the user may programmably unfreeze an output clock by writing logic ‘1’ to the respective enable bit.

The freeze logic will never force a newly–frozen clock to a logic ‘0’ state before the time at which it would normally transition there. The logic simply keeps the frozen clock at logic ‘0’ once it is there. Likewise, the freeze logic will never force a newly–unfrozen clock to a logic ‘1’ state before the time at which it would normally transition there. The logic re–enables the unfrozen clock during the time when the respective clock would normally be in a logic ‘0’ state, eliminating the possibility of ‘runt’ clock pulses.

The user may write to the Serial Input register through the Frz_Data input by supplying a logic ‘0’ start bit followed serially by 12 NRZ freeze enable bits. After the 12th freeze enable bit the Frz_Data signal must be left in (or returned to) a logic ‘1’ state (Figure 9). The period of each Frz_Data bit equals the period of the free–running Frz_Clk signal. The Frz_Data serial transmission should be timed so the MPC972 can sample each Frz_Data bit with the rising edge of the free–running Frz_Clk signal.

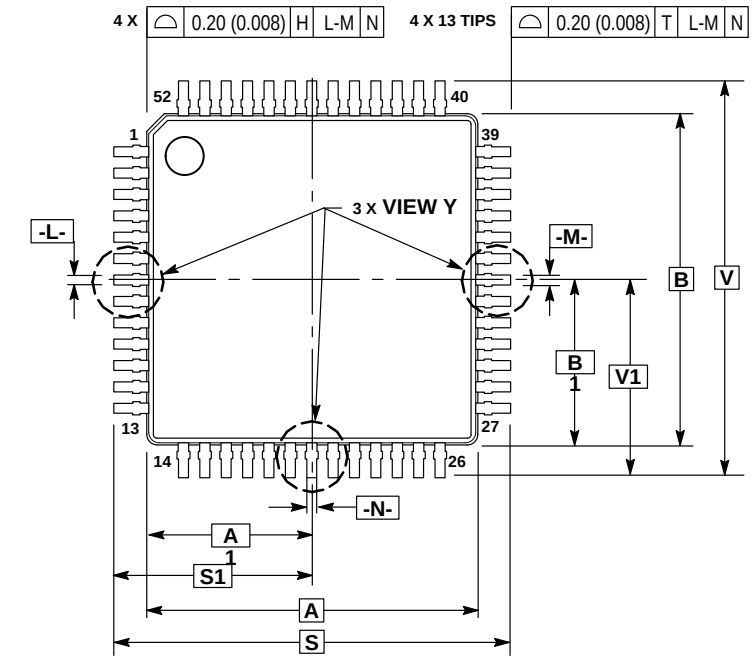


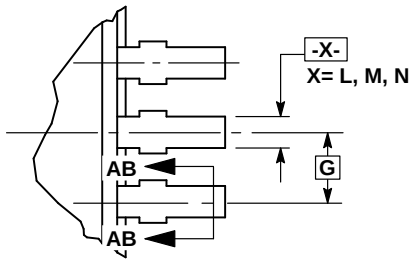
D0–D3 are the control bits for Qa0–Qa3, respectively
D4–D7 are the control bits for Qb0–Qb3, respectively
D8–D10 are the control bits for Qc1–Qc3, respectively
D11 is the control bit for QFB

Figure 9. Freeze Data Input Protocol

OUTLINE DIMENSIONS

FA SUFFIX
TQFP PACKAGE
CASE 848D-02
ISSUE A





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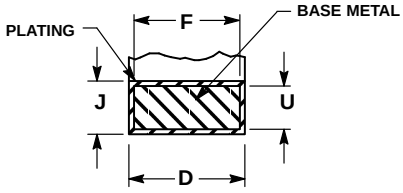
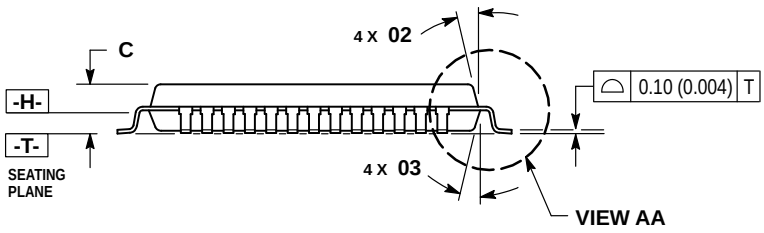
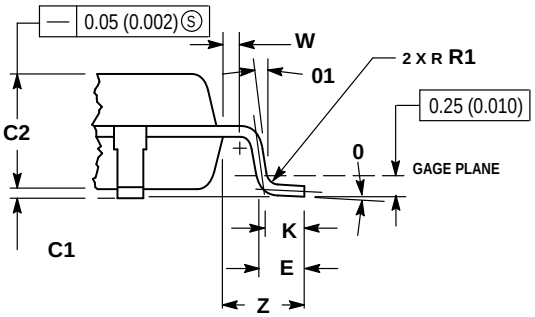


SECTION AB-AB
ROTATED 90° CLOCKWISE



VIEW AA



VIEW AA

NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DATUM PLANE -H- IS LOCATED AT BOTTOM OF LEAD AND IS COINCIDENT WITH THE LEAD WHERE THE LEAD EXITS THE PLASTIC BODY AT THE BOTTOM OF THE PARTING LINE.
4. DATUMS -L-, -M- AND -N- TO BE DETERMINED AT DATUM PLANE -H-.
5. DIMENSIONS S AND V TO BE DETERMINED AT SEATING PLANE -T-.
6. DIMENSIONS A AND B DO NOT INCLUDE MOLD PROTRUSION. ALLOWABLE PROTRUSION IS 0.25 (0.010) PER SIDE. DIMENSIONS A AND B DO INCLUDE MOLD MISMATCH AND ARE DETERMINED AT DATUM PLANE -H-.
7. DIMENSION D DOES NOT INCLUDE DAMBAR PROTRUSION. DAMBAR PROTRUSION SHALL NOT CAUSE THE LEAD WIDTH TO EXCEED 0.460 (0.018). MINIMUM SPACE BETWEEN PROTRUSION AND ADJACENT LEAD OR PROTRUSION 0.007 (0.003).

	MILLIMETERS		INCHES	
DIM	MIN	MAX	MIN	MAX
A	10.00 BSC		0.394 BSC	
A1	5.00 BSC		0.197 BSC	
B	10.00 BSC		0.394 BSC	
B1	5.00 BSC		0.197 BSC	
C	—	1.60	—	0.063
C1	0.05	0.15	0.002	0.006
C2	1.35	1.45	0.053	0.057
D	0.22	0.38	0.009	0.015
E	0.45	0.75	0.018	0.030
F	0.22	0.33	0.009	0.013
G	0.65 BSC		0.026 BSC	
J	0.09	0.20	0.004	0.008
K	0.50 REF		0.020 REF	
R1	0.10	0.20	0.004	0.008
S	12.00 BSC		0.472 BSC	
S1	6.00 BSC		0.236 BSC	
U	0.09	0.16	0.004	0.006
V	12.00 BSC		0.472 BSC	
V1	6.00 BSC		0.236 BSC	
W	0.20 REF		0.008 REF	
Z	1.00 REF		0.039 REF	
0	0°	7°	0°	7°
01	0°	—	0°	—
02	12° REF		12° REF	
03	5°	13°	5°	13°

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