

Quadrature Decode TPU Function (QDEC)

By Jeff Wright



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1 Functional Overview

The quadrature decode function is a TPU input function that uses two channels to decode a pair of out-of-phase signals in order to increment or decrement a (position) counter. It is particularly useful for decoding position and direction information from a slotted encoder in motion control systems, thus replacing expensive external solutions. **Figure 1** shows a typical application.

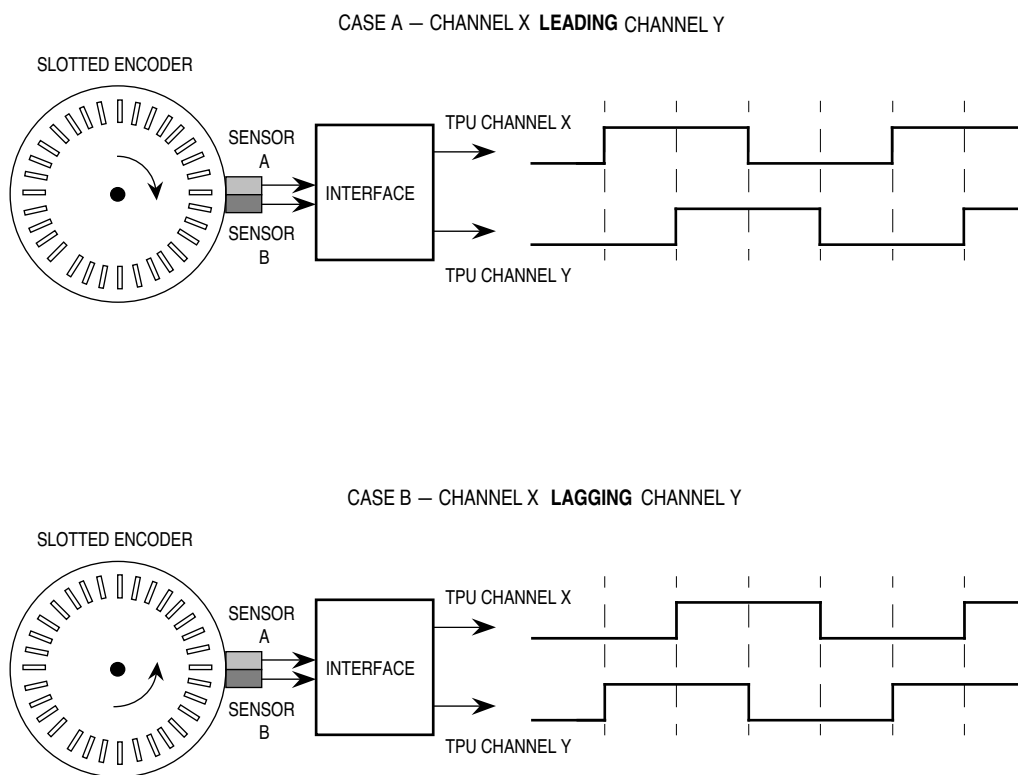


Figure 1 Typical QDEC Application

2 Detailed Description

The QDEC function uses a pair of TPU channels to decode quadrature signals into a 16-bit counter in parameter RAM. The counter is updated when a valid transition is detected on either one of the two inputs — full '4x' resolution is derived from the encoder signals. The counter is incremented or decremented depending on the lead/lag relationship of the two signals at the time of servicing the transition (See **Figure 2**). The user can read or write the counter at any time. The counter is free running, overflowing to \$0000 or underflowing to \$FFFF depending on direction.

In systems where the counter may overflow or underflow, since no interrupt requests are generated, the user must ensure that the CPU reads the counter periodically. Maximum period is \$8000 counts at maximum signal frequency. Two's complement arithmetic can then be used by the CPU to maintain position and direction information.

When initialized, the function is configured so that the first edge on either channel results in a counter update. In order to distinguish between the two channels, this note uses the convention of referring to the channel with the lower channel number as the primary channel. The other channel is referred to as the secondary channel.

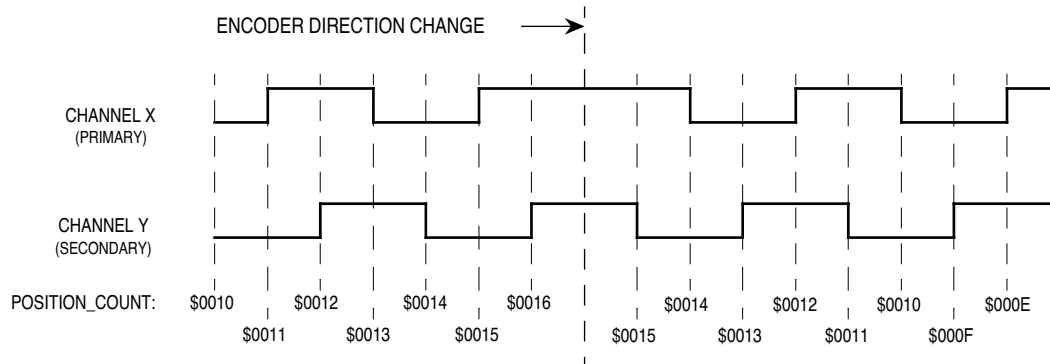


Figure 2 Normal Mode Operation

2.1 Time Stamp

The QDEC function provides a time stamp referenced to TCR1 for every valid signal edge. The host CPU can also request a current TCR1 value. These two features allow position and speed interpolation by the host CPU between quadrature edges at very slow count rates.

2.2 Discrete Input/Transition Counter

A single channel programmed to run QDEC can be used as a digital input pin with a transition counter.

3 Function Code Size

Total TPU function code size determines what combination of functions can fit into a given ROM or emulation memory microcode space. QDEC function code size is:

$$21 \mu \text{ instructions} + 8 \text{ entries} = \mathbf{29 \text{ long words}}$$

4 Function Parameters

This section provides detailed descriptions of function parameters stored in channel parameter RAM. **Figure 3** shows TPU parameter RAM address mapping. **Figure 4** shows the parameter RAM assignment used by the function. In the diagrams, $Y = M111$, where M is the value of the module mapping bit (MM) in the system integration module configuration register ($Y = \$7$ or $\$F$).

Channel Number	Base Address	Parameter Address							
		0	1	2	3	4	5	6	7
0	\$YFFF##	00	02	04	06	08	0A	—	—
1	\$YFFF##	10	12	14	16	18	1A	—	—
2	\$YFFF##	20	22	24	26	28	2A	—	—
3	\$YFFF##	30	32	34	36	38	3A	—	—
4	\$YFFF##	40	42	44	46	48	4A	—	—
5	\$YFFF##	50	52	54	56	58	5A	—	—
6	\$YFFF##	60	62	64	66	68	6A	—	—
7	\$YFFF##	70	72	74	76	78	7A	—	—
8	\$YFFF##	80	82	84	86	88	8A	—	—
9	\$YFFF##	90	92	94	96	98	9A	—	—
10	\$YFFF##	A0	A2	A4	A6	A8	AA	—	—
11	\$YFFF##	B0	B2	B4	B6	B8	BA	—	—
12	\$YFFF##	C0	C2	C4	C6	C8	CA	—	—
13	\$YFFF##	D0	D2	D4	D6	D8	DA	—	—
14	\$YFFF##	E0	E2	E4	E6	E8	EA	EC	EE
15	\$YFFF##	F0	F2	F4	F6	F8	FA	FC	FE

— = Not Implemented (reads as \$00)

Figure 3 TPU Channel Parameter RAM CPU Address Map

\$YFFFW0	EDGE_TIME*
\$YFFFW2	POSITION_COUNT*
\$YFFFW4	TCR1_VALUE
\$YFFFW6	CHAN_PINSTATE
\$YFFFW8	CORR_PINSTATE_ADDR
\$YFFFWA	EDGE_TIME_LSB_ADDR
\$YFFFWC	
\$YFFFWE	

W= Channel number

*One channel only. See text for detailed explanation.

Parameter Write Access:

	Written by CPU
	Written by TPU
	Written by CPU and TPU
	Unused parameters

**Figure 4 Function Parameter RAM Assignment
Primary and Secondary Channels**

4.1 TCR1_VALUE

This 16-bit parameter is updated by the TPU to contain the latest value of the TCR1 internal counter. TCR1_VALUE is updated on two occasions:

During initialization of the function.

During the service of a TCR1 read host service request issued by the host CPU.

This parameter can be used along with EDGE_TIME to perform position and speed interpolation at slow count rates. TCR1_VALUE can reside in the parameter RAM of either or both QDEC channels, but the parameter is only updated for the channel that receives the host service request from the CPU. Since the TPU must respond to the HSR before copying the TCR1 value to parameter RAM, the value obtained does not exactly correspond to the TCR1 value at the time the HSR is issued. The difference depends on the latency of the TPU and the prescaler value of TCR1. See **7 Performance and Use of Function** for details.

4.2 CHAN_PINSTATE

These 16-bit parameters (one for each channel) are maintained by the TPU. Each parameter contains a value that represents the logic level of the channel pin when the last valid transition was serviced. The value \$8000 is used to represent a pin high level, and \$0000 to represent a pin low level. When an edge is serviced, the new pin state is compared with the last pin state stored in CHAN_PINSTATE — if the states are the same, then a valid transition has not occurred (noise) and the counter is not updated.

The CHAN_PINSTATE parameters are also used to determine the phase (lead/lag) relationship between the two QDEC channels so that POSITION_COUNT is updated in the correct direction. To perform this lead/lag test, the channel compares its new pin state with the CHAN_PINSTATE parameter of the other QDEC channel (obtained via CORR_PINSTATE_ADDR) and from the relationship takes the appropriate action. See **9 Function Algorithm** for an explanation of the lead/lag tests.

The CPU must not write CHAN_PINSTATE parameters while QDEC is running, or an erroneous update of POSITION_COUNT can occur.

4.3 CORR_PINSTATE_ADDR

These parameters (one for each channel) are initialized by the CPU to contain the address in parameter RAM of the CHAN_PINSTATE parameter of the corresponding QDEC channel. They are used to obtain the CHAN_PINSTATE parameter of the corresponding channel for the lead/lag test. For example, if channels 0 and 1 are being used for QDEC, the CORR_PINSTATE_ADDR of channel 0 should be \$16 and CORR_PINSTATE_ADDR of channel 1 should be \$06. These parameters are written once prior to initialization and must not be changed while QDEC is running.

4.4 EDGE_TIME_LSB_ADDR

These parameters (one for each channel) are initialized by the CPU to contain the address in parameter RAM of the LSB (odd address) of the EDGE_TIME parameter. The EDGE_TIME_LSB_ADDR parameters of both QDEC channels must point to the same parameter RAM location for the QDEC function to operate correctly. This parameter is used to access both EDGE_TIME and POSITION_COUNT parameters. For example, if channels 0 and 1 are being used for QDEC and EDGE_TIME and POSITION_COUNT are chosen to reside in channel 1, then the EDGE_TIME_LSB_ADDR of both channels 0 and 1 must be programmed to \$11. These parameters are written once prior to initialization and must not be changed while QDEC is running.

4.5 EDGE_TIME

This 16-bit parameter, which resides in the parameter RAM of only one QDEC channel, is updated by the TPU when a valid signal transition is serviced on either channel. It contains the TCR1 value that was captured in hardware at the time of the signal transition — it thus provides a time stamp for the host CPU.

EDGE_TIME can reside in the parameter RAM of either QDEC channel, but because both parameters are referenced by the EDGE_TIME_LSB_ADDR address pointer, EDGE_TIME must be in the same parameter RAM as POSITION_COUNT. See **7 Performance and Use of Function** for more details.

4.6 POSITION_COUNT

This 16-bit counter is the primary output of the QDEC function. POSITION_COUNT resides in the parameter RAM of only one QDEC channel. POSITION_COUNT can be read or written at any time by the CPU. Normally, POSITION_COUNT is initialized by the CPU, then left to run as a free running counter.

POSITION_COUNT can reside in the parameter RAM of either QDEC channel, but because both parameters are referenced by the EDGE_TIME_LSB_ADDR address pointer, POSITION_COUNT must be in the same parameter RAM as EDGE_TIME.

4.7 HSQ0

Host sequence bit 0 is written by the CPU. HSQ0 is used by the TPU to determine whether the channel being serviced is the primary or secondary channel. HSQ0 of the primary channel must be cleared and HSQ0 of the secondary channel must be set. The primary channel is normally the channel with the lower channel number of the pair.

5 Host Interface to Function

This section provides information concerning the TPU host interface to the QDEC function. **Figure 5** is a TPU address map. Detailed TPU register diagrams follow the figure. In **Figure 5** and in the register diagrams, Y = M111, where M is the value of the module mapping bit (MM) in the system integration module configuration register (Y = \$7 or \$F).

Address	15	8	7	0
\$YFFE00	TPU MODULE CONFIGURATION REGISTER (TPUMCR)			
\$YFFE02	TEST CONFIGURATION REGISTER (TCR)			
\$YFFE04	DEVELOPMENT SUPPORT CONTROL REGISTER (DSCR)			
\$YFFE06	DEVELOPMENT SUPPORT STATUS REGISTER (DSSR)			
\$YFFE08	TPU INTERRUPT CONFIGURATION REGISTER (TICR)			
\$YFFE0A	CHANNEL INTERRUPT ENABLE REGISTER (CIER)			
\$YFFE0C	CHANNEL FUNCTION SELECTION REGISTER 0 (CFSR0)			
\$YFFE0E	CHANNEL FUNCTION SELECTION REGISTER 1 (CFSR1)			
\$YFFE10	CHANNEL FUNCTION SELECTION REGISTER 2 (CFSR2)			
\$YFFE12	CHANNEL FUNCTION SELECTION REGISTER 3 (CFSR3)			
\$YFFE14	HOST SEQUENCE REGISTER 0 (HSQR0)			
\$YFFE16	HOST SEQUENCE REGISTER 1 (HSQR1)			
\$YFFE18	HOST SERVICE REQUEST REGISTER 0 (HSRR0)			
\$YFFE1A	HOST SERVICE REQUEST REGISTER 1 (HSRR1)			
\$YFFE1C	CHANNEL PRIORITY REGISTER 0 (CPR0)			
\$YFFE1E	CHANNEL PRIORITY REGISTER 1 (CPR1)			
\$YFFE20	CHANNEL INTERRUPT STATUS REGISTER (CISR)			
\$YFFE22	LINK REGISTER (LR)			
\$YFFE24	SERVICE GRANT LATCH REGISTER (SGLR)			
\$YFFE26	DECODED CHANNEL NUMBER REGISTER (DCNR)			

Figure 5 TPU Address Map

CIER — Channel Interrupt Enable Register**\$YFFE0A**

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CH 15	CH 14	CH 13	CH 12	CH 11	CH 10	CH 9	CH 8	CH 7	CH 6	CH 5	CH 4	CH 3	CH 2	CH 1	CH 0

CH	Interrupt Enable
X	Not used by this function

CFSR[0:3] — Channel Function Select Registers**\$YFFE0C – \$YFFE12**

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CFS (CH 15, 11, 7, 3)				CFS (CH 14, 10, 6, 2)				CFS (CH 13, 9, 5, 1)				CFS (CH 12, 8, 4, 0)			

CFS[4:0] — Function Number (Assigned during microcode assembly)

HSQR[0:1] — Host Sequence Registers**\$YFFE14 – \$YFFE16**

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CH 15, 7		CH 14, 6		CH 13, 5		CH 12, 4		CH 11, 3		CH 10, 2		CH 9, 1		CH 8, 0	

CH[15:0]	Operating Mode
X0	Primary Channel
X1	Secondary Channel

HSRR[1:0] — Host Service Request Registers**\$YFFE18 – \$YFFE1A**

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CH 15, 7		CH 14, 6		CH 13, 5		CH 12, 4		CH 11, 3		CH 10, 2		CH 9, 1		CH 8, 0	

CH[15:0]	Action
00	No Host Service (Reset Condition)
01	Not Used
10	Read TCR1
11	Initialize

CPR[1:0] — Channel Priority Registers**\$YFFE1C – \$YFFE1E**

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CH 15, 7		CH 14, 6		CH 13, 5		CH 12, 4		CH 11, 3		CH 10, 2		CH 9, 1		CH 8, 0	

CH[15:0]	Channel Priority
00	Disabled
01	Low
10	Middle
11	High

CISR — Channel Interrupt Status Register**\$YFFE20**

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CH 15	CH 14	CH 13	CH 12	CH 11	CH 10	CH 9	CH 8	CH 7	CH 6	CH 5	CH 4	CH 3	CH 2	CH 1	CH 0

CH	Interrupt Status
X	Not used by this function

6 Function Configuration

The CPU configures the QDEC function as follows.

1. Disables the channels by clearing the two channel priority bits on each of the QDEC channels (not necessary from reset).
2. Selects the QDEC function on both channels by writing the QDEC function number to their function select bits.
3. Initializes CORR_PINSTATE_ADDR and EDGE_TIME_LSB_ADDR in parameter RAM of both channels.
4. Initializes POSITION_COUNT to the desired start value.
5. Selects one channel as the primary channel and the other as the secondary channel via HSQ0.
6. Issues an HSR %11 to each channel to initialize the function.
7. Enables servicing by assigning H, M, or L priority to the channel priority bits. Both QDEC channels must be assigned the same priority to ensure correct operation.

The TPU then executes the initialization state and starts decoding the two input signals. When initialization is complete, the HSR bit values for both channels are %00.

NOTE

CHAN_PINSTATE parameters must not be read by the CPU until after the TPU has negated the HSR bits during initialization.

7 Performance and Use of Function

7.1 Performance

Like all TPU functions, the performance limit of the QDEC function in a given application is dependent upon the service time (latency) of other active TPU channels. This is due to the operational nature of the scheduler. When a pair of QDEC channels are being used and no other TPU channels are active, the minimum time between count edges on the two channels is 42 CPU clock cycles. This is equivalent to a count rate of approximately 400,000 counts per second with a system clock speed of 16.78 MHz, or a count rate of approximately 500,000 counts per second with a system clock speed of 20.97 MHz.

Table 1 Quadrature Decode Function — State Timing

State Number and Name	Max. CPU Clock Cycles	RAM Accesses by TPU
S1 INIT_QDEC	12	3
S2 READ_TCR1_QDEC	2	1
S3 EDGE_QDEC	28	8

NOTE: Execution times do not include the time slot transition time (TST = 10 or 14 CPU clocks)

When more TPU channels are active, performance is lessened — if two sets of encoder signals are decoded using four channels, then the maximum count rate with a 16.78-kHz bus is limited to approximately 200,000 counts. Use of other functions, such as PWM, also lessens performance.

Since the scheduler assures that worst-case latencies in any TPU application can be closely estimated, it is recommended that the guidelines in the *TPU Reference Manual* (TPURM/AD) be used with the figures given in the quadrature decode function state timing table to perform an analysis of any proposed application that appears to approach the performance limits of the TPU. If the QDEC function fails to meet the system performance requirements, then fast quadrature decode (FQD) TPU function should be evaluated as an alternative.

7.2 Accuracy

Since the TPU takes time to respond to an input transition, there is always a one LSB uncertainty in a CPU read of POSITION_COUNT while the input signals are active. These uncertainties only apply while an external system such as a motor is active. After the system has been brought to a stop, and the last transition has been serviced, POSITION_COUNT is accurate.

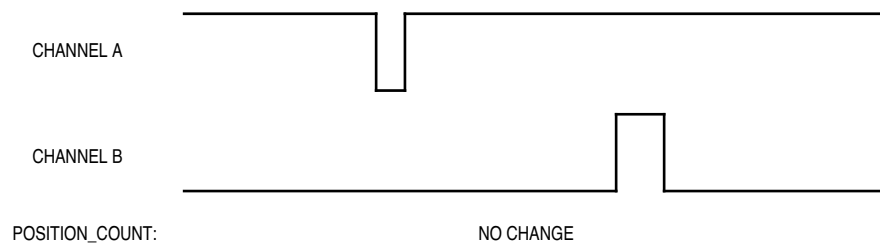
7.3 Noise Immunity

To a large extent, TPU hardware and the QDEC function microcode protect the counter from erroneous updates due to noise. All TPU input channels incorporate a digital filter which rejects pulses of less than two CPU clocks and guarantees to pass pulses of greater than four CPU clocks. In addition, when servicing a transition in normal mode, the QDEC function always checks the new pin state against the pin state from the last service, and if they are equal then no action is taken. This protects against a noise pulse that is long enough to get through the digital filter, but not long enough to last from the actual transition time to the time that the TPU services the channel.

Despite these precautions, there may be situations where noise on both channels simultaneously causes erroneous updates of the counter. Under these conditions, it is recommended that additional external protection, such as Schmitt trigger buffers or an additional filter stage, be added.

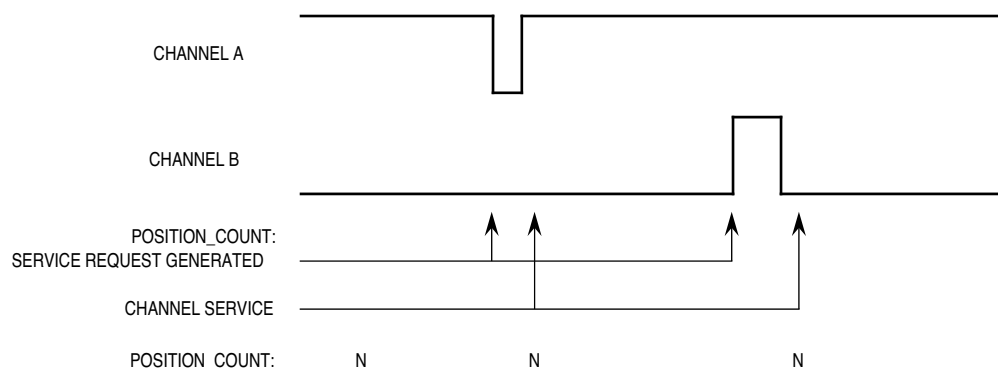
The following examples are intended to illustrate the extent of the noise immunity inherent in the TPU itself and the QDEC function.

CASE A: Short positive or negative pulses two CPU clocks or less in duration.



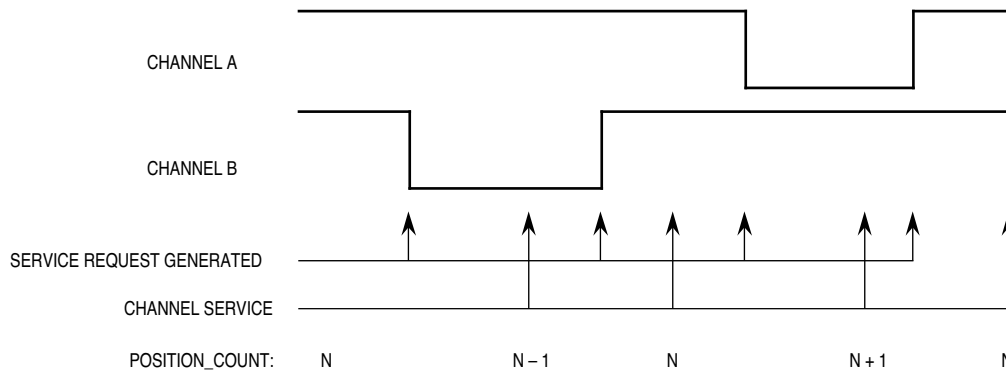
Result: Rejected by hardware filter on TPU input pins — no service requests.

CASE B: Positive or negative pulses four CPU clocks or greater in duration, but less than TPU service latency at the time of the pulse.



Result: One service request per pulse — rejected in software by pin state history test.

CASE C: Positive or negative pulses four CPU clocks or greater in duration and greater than TPU service latency at the time of the pulse.



Result: Two service requests per pulse. Both edges are serviced and counted resulting in a net error of zero on POSITION_COUNT.

Pulses of three CPU clocks in length may pass through the input filter — they can either be case A or case B. Noise rejection cannot be guaranteed when case C noise exists simultaneously on both channels.

7.4 Using QDEC with Three-Signal Encoders

Many shaft encoders supply two quadrature signals plus an index signal that generates a pulse once per revolution. This pulse usually has a fixed relationship to other system parameters and is used for alignment during startup.

Three-signal encoders can be decoded when QDEC is used in conjunction with the TPU function called new input transition counter (NITC). QDEC decodes the quadrature signals and the index pulse is fed to the NITC channel. NITC allows any location in parameter RAM to be captured on a specified edge and the value presented to the CPU. In this case, NITC would be configured to capture the POSITION_COUNT parameter of QDEC. The NITC channel should be run on a lower channel number than the QDEC primary channel, and assigned the same priority as the QDEC channel.

7.5 Using the Time Stamp Feature

The time stamp feature has been provided to allow the CPU to perform speed and position interpolation at very slow encoder speeds. At low speeds, the number of transitions counted between CPU reads of POSITION_COUNT is too small to provide reliable information. Due to the following restrictions, the time stamp feature should be used with care.

7.6 EDGE_TIME and POSITION_COUNT Coherency

The TPU cannot coherently update both the EDGE_TIME and POSITION_COUNT parameters during the service of a transition. A CPU read of these two parameters may return values that do not correlate, such as a new EDGE_TIME with an 'old' POSITION_COUNT value (EDGE_TIME is updated first).

This problem can be handled by performing multiple CPU reads of the two parameters with a delay between the reads. The delay must be greater than or equal to the worst-case time between the TPU writing EDGE_TIME and POSITION_COUNT of ten CPU clocks. For example, the following CPU action could be used.

```

GET_PARAM:      Read EDGE_TIME and POSITION_COUNT
LOOP:           Store EDGE_TIME in TEMP1 and POSITION_COUNT in TEMP2
                Delay 10 CPU clocks
                Read EDGE_TIME and POSITION_COUNT
                If EDGE_TIME  $\neq$  TEMP1 or POSITION_COUNT  $\neq$  TEMP2 then
                    goto LOOP
                Endif
VALID:          TEMP1 and TEMP2 are coherent and valid.

```

7.7 TCR1 Timebase Read

To actually perform interpolation, the CPU must obtain valid EDGE_TIME and POSITION_COUNT parameters as described above, then read the TCR1 timebase at fixed intervals to calculate a new position.

Since the CPU must issue an HSR to obtain the latest TCR1_VALUE, and since that HSR is subject to normal TPU scheduling, there is an uncertainty in the returned TCR1_VALUE that is dependent upon both TPU latency at the time of issuing the HSR and upon the selected prescaler value for TCR1.

In the best case (TPU idle at time of HSR issue) there is a delay equivalent to 16 CPU clocks between the time the CPU writes the HSR bits and the time the TPU writes TCR1_VALUE and clears the HSR bits.

7.8 Using QDEC as a Discrete Input/Transition Counter

A single TPU channel programmed to run QDEC can be used as a discrete input pin and transition counter. To be used in this way, the channel must be programmed as a primary channel. The EDGE_TIME_LSB_ADDR parameter must point to the LSB of the channel's own parameter 0 and the CORR_PINSTATE_ADDR parameter must point to the channel's own CHAN_PINSTATE parameter. An HSR %11 should be issued to initialize the function.

When the QDEC function is configured as described, CHAN_PINSTATE is updated as each transition is serviced, and contains a value representing the latest pin level (\$8000 = high, \$0000 = low). POSITION_COUNT holds the number of transitions on the pin (positive and negative).

An immediate update of CHAN_PINSTATE can be invoked at any time by issuing an HSR %11. The CPU should not interpret the value of CHAN_PINSTATE until the TPU has completed the host service request and the HSR bits have been negated.

8 Function Examples

The following examples show configuration of the quadrature decode function for both quadrature decode and for operation as an input pin with transition counter. Each example includes a description of the example, a diagram of the initial parameter RAM content, and the initial control bit settings.

8.1 Example A

8.1.1 Description

Configure channels 1 and 2 to run QDEC. The initial position should be \$1000.

8.1.2 Initialization

Disable channels 1 and 2 by clearing priority bits (CPR1[3:2] and CPR1[5:4]). Select QDEC function by programming the function select register of each channel. Configure parameter RAM of each channel as shown below. Write HSQR1[3:2] = %00 (channel 1 primary) and HSQR1[5:4] = %01 (channel 2 secondary). Write HSRR1[3:2] and HSRR1[5:4] = %11 to initialize both channels and start quadrature decode. Write the priority bits of both channels to the same non-zero value.

Table 2 Channel 1 (Primary) Parameter RAM

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
\$YFFF10	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	EDGE_TIME
\$YFFF12	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	POSITION_COUNT
\$YFFF14	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	TCR1_VALUE
\$YFFF16	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	CHAN_PINSTATE
\$YFFF18	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0		\$26
\$YFFF1A	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1		\$11

POSITION_COUNT = \$1000

Table 3 Channel 2 (Secondary) Parameter RAM

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
\$YFFF20	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
\$YFFF22	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
\$YFFF24	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	TCR1_VALUE
\$YFFF26	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	CHAN_PINSTATE
\$YFFF28	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0		\$16
\$YFFF2A	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1		\$11

The function now runs, decodes transitions on channel 1 or 2, and increments or decrements POSITION_COUNT accordingly. The CPU can read or write POSITION_COUNT at any time.

8.2 Example B

8.2.1 Description

Configure channel 12 to act as an input pin with a transition counter. Initialize the counter to zero.

8.2.2 Initialization

Disable channel 12 by clearing priority bits (CPR0[9:8]). Select QDEC function by programming the function select register of channel 12. Configure channel 12 parameter RAM as shown below. Write HSQR0[9:8] = %00 (primary channel). Write HSRR0[9:8] = %11 to channel 12 to initialize, read pin level and start counting transitions. Write channel 12 priority bits to a non-zero value.

Table 4 Channel 12 Parameter RAM

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
\$YFFFC0	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	EDGE_TIME
\$YFFFC2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	TRANS_COUNT
\$YFFFC4	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	TCR1_VALUE
\$YFFFC6	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	CHAN_PINSTATE
\$YFFFC8	0	0	0	0	0	0	0	1	1	0	0	0	1	1	0		\$C6
\$YFFCA	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1		\$C1

TRANS_COUNT (POSITION_COUNT) = \$0000

The function now runs, detects transitions on channel 12, and increments the transition counter (POSITION_COUNT) accordingly. On completion of the initialization HSR and any subsequent edge service, the parameter CHAN_PINSTATE contains the latest level of the channel pin (\$8000 for high, \$0000 for low). The CPU can read or write the transition counter at any time.

Note that the TCR1 read HSR can still be used when QDEC is operating in this mode.

9 Function Algorithm

The quadrature decode function consists of three states, which operate as described below. The following description is provided as a guide only, to aid understanding of the function. The exact sequence of operations in microcode may be different to optimize speed and code size. TPU microcode source listings for all functions in the TPU function library can be downloaded from the Motorola Freeware bulletin board. Refer to *Using the TPU Function Library and TPU Emulation Mode* (TPUPN00/D) for detailed instructions on downloading and compiling microcode.

9.1 STATE 1: INIT_QDEC

This state is entered as a result of a host service request type %11.

```
The channel is configured as an input with TCR1 as a timebase
The pin is configured to detect any transition
Transition service requests are enabled
The current pin state is read
If the pin is low
    $0000 is stored in CHAN_PINSTATE
Else
    $8000 is stored in CHAN_PINSTATE
Endif
The current value of TCR1 is read and stored in TCR1_VALUE
The state ends
```

9.2 STATE 2: READ_TCR1_QDEC

This state is entered as a result of a host service request type %10.

```
The current value of TCR1 is read and stored in TCR1_VALUE
The state ends
```

9.3 STATE 3: EDGE_QDEC

This state is entered as a result of a transition on a QDEC channel pin.

```
The channel pin state is read
The transition latch is cleared to enable detection of further edges
If the new pin state = CHAN_PINSTATE
    The state ends (noise)
Endif
If the pin is low
    $0000 is stored in CHAN_PINSTATE
Else
    $8000 is stored in CHAN_PINSTATE
Endif
The TCR1 value captured at the time of the edge is stored in EDGE_TIME
```

Using this new pin state along with the pin state of the other QDEC channel and host sequence bit 0 (primary or secondary channel), POSITION_COUNT is incremented or decremented by one according to the lead/lag tests explained below.

9.4 Explanation of Lead/Lag Test

The lead/lag test is performed to determine the phase relationship of the two QDEC signals and hence whether to increment or decrement the parameter POSITION_COUNT. The CHAN_PINSTATE parameters of the two channels are added together and the resulting N bit is used along with the edge type and channel type (primary or secondary — host sequence bit 0) to result in the following operation:

Lead/Lag Test Results

Serviced Transition	Test Description
Primary Rising	If last secondary transition was falling, then primary channel is leading secondary channel and POSITION_COUNT is incremented. If last secondary transition was rising, then primary channel is lagging secondary channel and POSITION_COUNT is decremented.
Primary Falling	If last secondary transition was rising, then primary channel is leading secondary channel and POSITION_COUNT is incremented. If last secondary transition was falling, then primary channel is lagging secondary channel and POSITION_COUNT is decremented.
Secondary Rising	If last primary transition was rising, then primary channel is leading secondary channel and POSITION_COUNT is incremented. If last primary transition was falling, then primary channel is lagging secondary channel and POSITION_COUNT is decremented.
Secondary Falling	If last primary transition was falling, then primary channel is leading secondary channel and POSITION_COUNT is incremented. If last primary transition was rising, then primary channel is lagging secondary channel and POSITION_COUNT is decremented.

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