



## OVP Guide to Using Processor Models

### Model Specific Information for variant MIPS32\_24KEf

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## **Model Release Status**

This model is released as part of OVP releases and is included in OVPworld packages. Please visit [OVPworld.org](http://OVPworld.org).

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## 1 Overview

This document provides the details of an OVP Fast Processor Model variant. OVP Fast Processor Models are written in C and provide a C API for use in C based platforms. The models also provide a native interface for use in SystemC TLM2 platforms. The models are written using the OVP VMI API that provides a Virtual Machine Interface that defines the behavior of the processor. The VMI API makes a clear line between model and simulator allowing very good optimization and world class high speed performance. Most models are provided as a binary shared object and also as source. This allows the download and use of the model binary or the use of the source to explore and modify the model.

The models are run through an extensive QA and regression testing process and most model families are validated using technology provided by the processor IP owners.

There is a companion document (OVP Guide to Using Processor Models) which explains the general concepts of OVP Fast Processor Models and their use. It is downloadable from the OVPworld website documentation pages.

### *1.1 Description*

MIPS32 Configurable Processor Model

### *1.2 Licensing*

Usage of binary model under license governing simulator usage. Source of model available under Imperas Software License Agreement.

### *1.3 Limitations*

If this model is not part of your installation, then it is available for download from [www.OVPworld.org/MIPUser](http://www.OVPworld.org/MIPUser).

### *1.4 Verification*

Models have been validated correct as part of the MIPS Verified program and run through the MIPS AVP test programs

### *1.5 Features*

MIPS32 Instruction set implemented

MMU Type: Standard TLB

FPU implemented

L1 I and D cache model in either full or tag-only mode implemented (disabled by default)

Vectored interrupts implemented

MIPS16e ASE implemented

DSP ASE implemented

## 2 Configuration

### *2.1 Location*

The model source and object file is found in the VLNV tree at:

[mips.ovpworld.org/processor/mips32/1.0](http://mips.ovpworld.org/processor/mips32/1.0)

### *2.2 GDB Path*

The default GDB for this model is found at:

`$IMPERAS_HOME/lib/$IMPERAS_ARCH/gdb/mips-sde-elf-gdb`

### *2.3 Semi-Host Library*

The default semi-host library file is found in the VLNV tree at :

[mips.ovpworld.org/semihosting/mips32Newlib/1.0](http://mips.ovpworld.org/semihosting/mips32Newlib/1.0)

### *2.4 Processor Endian-ness*

This model can be set to either endian-ness (normally by a pin, or the ELF code).

### *2.5 QuantumLeap Support*

This processor is qualified to run in a QuantumLeap enabled simulator.

### *2.6 Processor ELF Code*

The ELF code supported by this model is: 0x8

### 3 Other Variants in this Model

Table 1. All variants in this model

Variant
ISA
M14K
M14KcTLB
M14KcFMM
4KEc
4KEm
4KEp
M4K
4Kc
4Km
4Kp
24Kc
24Kf
24KEc
24KEf
34Kc
34Kf
34Kn
74Kc
74Kf
1004Kc
1004Kf
1074Kc
1074Kf
microAptivC
microAptivP
microAptivCF
interAptiv
interAptivUP
proAptiv

### 4 Bus Ports

Table 2. Bus Ports

Type	Name	min	max
master (initiator)	INSTRUCTION	10	36
master (initiator)	DATA	10	36

## 5 Net Ports

Table 3. Net Ports

Name	Type	Description
reset	input	Core reset
dint	input	Debug external interrupt
SI_UseExceptionBase	input	SI_UseExceptionBase input (mask=0x00000001)
SI_ExceptionBase	input	SI_ExceptionBase input (mask=0xffff000)
hwint0	input	External interrupt
hwint1	input	External interrupt
hwint2	input	External interrupt
hwint3	input	External interrupt
hwint4	input	External interrupt
hwint5	input	External interrupt
nmi	input	Non-maskable external interrupt

## 6 FIFO Ports

No FIFO Ports in this model.

## 7 Parameters

Table 4. Parameters that can be set in the model, type: CPU

Name	Type	Description
cacheenable	Enumeration	Select cache model mode default=0 tag=1 full=2
cachedebug	Uns32	Cache debug flags
cacheextbiuinfo	Pointer	Pointer to platform-provided BIU cache info structure
mipsHexFile	String	Load a MIPS hex file (test-mode)
IMPERAS_MIPS_AVP_OPCODES	Boolean	Enable MIPS-specific magic Pass/Fail opcodes (specific for AVP test termination)
cacheIndexBypassTLB	Boolean	When set, cache index ops do not generate TLB exceptions
MIPS_TRACE	Boolean	Enable MIPS-format trace output
supervisorMode	Boolean	Override whether processor implements supervisor mode
busErrors	Boolean	Override bus error exception behavior. When true, accesses of memory not defined by platform will cause bus error exceptions
fixedMMU	Boolean	Override the MMU type to fixed mapping when true (sets Config.MT=3, Config.KU/K23=2 and Config1.MMUSizeM1=0)
removeDSP	Boolean	Override the DSP-present configuration when true (sets Config3.DSPP/DSP2P=0)

removeCMP	Boolean	Override the CMP-Present configuration when true (sets Config3.CMGCR and GCR_BASE to 0)
removeFP	Boolean	Override the FP-Present configuration when true (sets Config1.FP to 0)
isISA	Boolean	Enable to specify ISA model (reset address from ELF, all coprocessors enabled)
hiddenTLBentries	Boolean	Deprecated - Instead set config1MMUSizeM1 to maximum value to improve performance
ITCNumEntries	Uns32	Specify number of ITC cells present (MT cores only)
ITCNumFIFO	Uns32	Specify number of ITC FIFO cells in reference ITC implementation (MT cores only)
MTFPU	Uns32	Enable multi-threaded FPU (1:old mttc1 behavior, 2:new mttc1 behavior)
supportDenormals	Boolean	Enable to specify that the FPU supports denormal operands and results
VPE0MaxTC	Uns32	Specifies the maximum TCs initially on VPE0
mpuRegions	Uns32	Number of regions for memory protection unit
mpuType	Uns32	Type of MPU implementation
mpuEnable	Boolean	Enable MPU2 segment control at reset
mpuSegment0	Uns32	Attributes for segment 0 in MPU2 SegmentControl_0 register
mpuSegment1	Uns32	Attributes for segment 1 in MPU2 SegmentControl_0 register
mpuSegment2	Uns32	Attributes for segment 2 in MPU2 SegmentControl_0 register
mpuSegment3	Uns32	Attributes for segment 3 in MPU2 SegmentControl_0 register
mpuSegment4	Uns32	Attributes for segment 4 in MPU2 SegmentControl_1 register
mpuSegment5	Uns32	Attributes for segment 5 in MPU2 SegmentControl_1 register
mpuSegment6	Uns32	Attributes for segment 6 in MPU2 SegmentControl_1 register
mpuSegment7	Uns32	Attributes for segment 7 in MPU2 SegmentControl_1 register
mpuSegment8	Uns32	Attributes for segment 8 in MPU2 SegmentControl_2 register
mpuSegment9	Uns32	Attributes for segment 9 in MPU2 SegmentControl_2 register
mpuSegment10	Uns32	Attributes for segment 10 in MPU2 SegmentControl_2 register
mpuSegment11	Uns32	Attributes for segment 11 in MPU2 SegmentControl_2 register
mpuSegment12	Uns32	Attributes for segment 12 in MPU2 SegmentControl_3 register



mpuSegment13	Uns32	Attributes for segment 13 in MPU2 SegmentControl_3 register
mpuSegment14	Uns32	Attributes for segment 14 in MPU2 SegmentControl_3 register
mpuSegment15	Uns32	Attributes for segment 15 in MPU2 SegmentControl_3 register
mvpconf0vpe	Uns32	Override MVPConf0.PVPE
mvpconf0tc	Uns32	Override MVPConf0.PTC
mvpconf0pcp	Boolean	Override MVPConf0.PCP
mvpconf0tcp	Boolean	Override MVPConf0.TCP
hasFDC	Uns32	Specify the size of Fast Debug Channel register block
statusFR	Boolean	Override power on value in Status.FR (Floating point register mode)
configDSP	Boolean	Override Config.DSP (data scratchpad RAM present)
configISP	Boolean	Override Config.ISP (instruction scratchpad RAM present)
configK0	Uns32	Override power on value of Config.K0 (set Kseg0 cacheability)
configKU	Uns32	Override power on value of Config.KU (set Useg cacheability)
configK23	Uns32	Override power on value of Config.K23 (set Kseg23 cacheability)
configMDU	Boolean	Override Config.MDU (iterative multiply/divide unit)
configMM	Boolean	Override Config.MM (merging mode for write)
configMT	Uns32	Override Config.MT
configSB	Boolean	Override Config.SB (simple bus transfers only)
MIPS16eASE	Boolean	Override Config1.CA (enables the MIPS16e ASE)
config1DA	Uns32	Override Config1.DA (Dcache associativity)
config1DL	Uns32	Override Config1.DL (Dcache line size)
config1DS	Uns32	Override Config1.DS (Dcache sets per way)
config1EP	Boolean	Override Config1.EP (EJTag present)
config1IA	Uns32	Override Config1.IA (Icache associativity)
config1IL	Uns32	Override Config1.IL (Icache line size)
config1IS	Uns32	Override Config1.IS (Icache sets per way)
config1MMUSizeM1	Uns32	Override Config1.MMUSizeM1 (number of MMU entries-1)
config1WR	Boolean	Override Config1.WR (watchpoint registers present)
config1FP	Boolean	Override Config1.FP (FPU present)
config3BI	Boolean	Override Config3.BI

config3BP	Boolean	Override Config3.BP
config3CDMM	Boolean	Override Config3.CDMM
config3CTXTC	Boolean	Override Config3.CTXTC
config3DSPP	Boolean	Override Config3.DSPP
config3DSP2P	Boolean	Override Config3.DSP2P
config3IPLW	Uns32	Override Config3.IPLW
config3ISA	Uns32	Override Config3.ISA
config3ISAOnExc	Boolean	Override Config3.ISAOnExc
config3ITL	Boolean	Override Config3.ITL
config3MCU	Boolean	Override Config3.MCU
config3MMAR	Uns32	Override Config3.MMAR
config3RXI	Boolean	Override Config3.RXI
config3SC	Boolean	Override Config3.SC
config3ULRI	Boolean	Override Config3.ULRI
externalinterrupt	Boolean	Override Config3.VEIC (enables the use of an external interrupt controller)
vectoredinterrupt	Boolean	Override Config3.VInt (enables vectored interrupts)
config3VZ	Boolean	Override Config3.VZ
config4AE	Boolean	Override Config4.AE
config4IE	Uns32	Override Config4.IE
config4MMUConfig	Uns32	Override Config4.MMUConfig field (interpretation depends on MMUExtDef value)
config4MMUExtDef	Uns32	Override Config4.MMUExtDef
config4VTLBSizeExt	Uns32	Override Config4.VTLBSizeExt
config5EVA	Boolean	Override Config5.EVA
config5NFExists	Boolean	Override Config5.NFExists
config5MSAEn	Boolean	Override Config5.MSAEn
config6FTLBEEn	Boolean	Override power on value of Config6.FTLBEEn
config7AR	Boolean	Override Config7.AR (Alias removed Data cache)
config7DCIDX_MODE	Uns32	Override Config7.DCIDX_MODE
config7HCI	Boolean	Override Config7.HCI (Hardware Cache Initialization)
config7IAR	Boolean	Override Config7.IAR (Alias removed Instruction cache)
config7WII	Boolean	Override Config7.WII (wait IE/IXMT ignore)
fcsrABS2008	Boolean	Override FCSR.ABS2008 (ABS/NEG compliant with IEEE 754-2008)
fcsrNaN2008	Boolean	Override FCSR.NAN2008 (QNaN/SNaN encodings match IEEE 754-2008 recommendation)
firPS	Boolean	Override FIR.PS (PS floating point type implemented)

firHas2008	Boolean	Override FIR.Has2008 (one or more IEEE 754-2008 features present)
intctlIPFDC	Uns32	Override IntCtl.IPFDC
intctlIPTI	Uns32	Override IntCtl.IPTI
pridRevision	Uns32	Override PRId.Revision
srsctlHSS	Uns32	Override SRSCtl.HSS (number of shadow register sets)
ExceptionBase	Uns32	Specify the BEV Exception Base address. (use GCR_Cx_RESET_BASE on CMP processors)
UseExceptionBase	Boolean	Set to one to use ExceptionBase[29:12] as the corresponding BEV address bits
firstBEVExceptionBaseMaskBit	Uns32	Specify LSB position of GCR_Cx_RESET_EXT_BASE. BEVExceptionBaseMask field. Only used when SegCtl present
EVAReset	Boolean	Set to one to reset into non-legacy address map and BEV location. Only used when non-CMP and SegCtl present
ExceptionBaseMask	Uns32	Specify the ExceptionBaseMask value used for bits [27:firstBEVExceptionBaseMaskBit]. Only used when non-CMP and SegCtl present
ExceptionBasePA	Uns32	Bits [35:29] of the physical address for the BEV overlays. Only used when non-CMP and SegCtl present
EIC_OPTION	Uns32	Override the external interrupt controller EIC_OPTION
ISPRAM_SIZE	Uns32	Encoded size of the ISPRAM region (log2(<ISPRAM size in bytes>) - 11)
ISPRAM_BASE	Uns64	Starting physical address of the ISPRAM region
ISPRAM_ENABLE	Boolean	Set the enable bit of the ISPRAM region's tag (used to enable the ISPRAM region prior to reset)
ISPRAM_FILE	String	Load a MIPS hex file into the ISPRAM region prior to reset
DSPRAM_SIZE	Uns32	Encoded size of the DSPRAM region (log2(<DSPRAM size in bytes>) - 11)
DSPRAM_BASE	Uns64	Starting physical address of the DSPRAM region
DSPRAM_ENABLE	Boolean	Set the enable bit of the DSPRAM region's tag (used to enable the DSPRAM region prior to reset)

## 8 Execution Modes

Table 5. CPU modes implemented in the model, type: CPU

Name	Code
KERNEL	0
DEBUG	1
SUPERVISOR	2
USER	3

## 9 Exceptions

Table 6. Exceptions handled by the model, type: CPU

Name	Code
Int	0
Mod	1
TLBL	2
TLBS	3
AdEL	4
AdES	5
IBE	6
DBE	7
Sys	8
Bp	9
RI	10
CpU	11
Ov	12
Tr	13
FPE	15
Impl1	16
Impl2	17
C2E	18
TLBRI	19
TLBXI	20
MDMX	22
WATCH	23
MCheck	24
Thread	25
DSPDis	26
Prot	29
CacheErr	30

## 10 Hierarchy of the model

A CPU core may allow the user to configure it to instance many processors of a Symmetrical Multi Processor (SMP). A CPU core may also have sub elements within a processor, for example hardware threading blocks.

OVP processor models can be written to include SMP blocks and to have many levels of hierarchy.

Some OVP CPU models may have a fixed hierarchy, and some may be configured by settings in a configuration register. Please see the register definitions of this model.

This model documentation shows the settings and hierarchy of the default settings for this model variant.

### 10.1 Level 1: CPU

This level in the model hierarchy has 16 commands.

This level in the model hierarchy has 5 register groups:

Table 7. Register groups

Group name	Registers
Core	33
FPU	34
DSP	9
COP0	43
Integration_support	1

This level in the model hierarchy has no children.

## 11 Model Commands

### 11.1 Level 1: CPU

#### 11.1.1 *isync*

specify instruction address range for synchronous execution

Table 8. *isync* command arguments

Argument	Type	Description
-addresshi	Uns64	end address of synchronous execution range
-addresslo	Uns64	start address of synchronous execution range

#### 11.1.2 *itrace*

enable or disable instruction tracing

Table 9. *itrace* command arguments

Argument	Type	Description
-after	Uns64	apply after this many instructions
-enable	Boolean	enable instruction tracing
-instructioncount	Boolean	include the instruction number in each trace
-off	Boolean	disable instruction tracing
-on	Boolean	enable instruction tracing
-registerchange	Boolean	show registers changed by this instruction
-registers	Boolean	show registers after each trace

#### 11.1.3 *mipsCOP0*

query a COP0 register value using <register> <select>

Table 10. *mipsCOP0* command arguments

Argument	Type	Description
-register	Int32	specify the COP0 register number
-select	Int32	specify the COP0 register select

#### 11.1.4 *mipsCacheDisable*

##### 11.1.4.1 *Argument description*

Disables tag or full cache model

#### 11.1.5 *mipsCacheEnable*

enable tag or full cache model

Table 11. *mipsCacheEnable* command arguments

Argument	Type	Description
----------	------	-------------

-debug	Int32	set cache model debug flags
-full	Boolean	enable full cache model
-tag	Boolean	enable cache tag line only model

### ***11.1.6 mipsCacheRatio***

Report current hit ratio for selected cache

Table 12. mipsCacheRatio command arguments

<b>Argument</b>	<b>Type</b>	<b>Description</b>
-dcache	Boolean	report hit ratio for dcache
-icache	Boolean	report hit ratio for icache

### ***11.1.7 mipsCacheReport***

#### ***11.1.7.1 Argument description***

Report current cache statistics

### ***11.1.8 mipsCacheReset***

#### ***11.1.8.1 Argument description***

reset the cache model

### ***11.1.9 mipsCacheTrace***

Control the tracing of cache accesses

Table 13. mipsCacheTrace command arguments

<b>Argument</b>	<b>Type</b>	<b>Description</b>
-noartifact	Boolean	filter artifact accesses
-nocached	Boolean	filter cached accesses
-nodcache	Boolean	filter dcache accesses
-noicache	Boolean	filter icache accesses
-notrue	Boolean	filter true accesses
-nouncached	Boolean	filter uncached accesses
-off	Boolean	turn off the cache tracing
-on	Boolean	turn on the cache tracing

### ***11.1.10 mipsDebugFlags***

Set the processor model debug flags to <value>

Table 14. mipsDebugFlags command arguments

<b>Argument</b>	<b>Type</b>	<b>Description</b>
-value	Int32	specify model debug flags

### ***11.1.11 mipsReadRegister***

Read a processor register using <resource> <offset>

Table 15. mipsReadRegister command arguments

Argument	Type	Description
-offset	Int32	the processor register offset
-resource	Int32	the processor register resource number

### ***11.1.12 mipsReadTLBEntry***

read a TLB entry specified by the index

Table 16. mipsReadTLBEntry command arguments

Argument	Type	Description
-index	Uns64	select the TLB entry

### ***11.1.13 mipsTLBDump***

#### ***11.1.13.1 Argument description***

Dumps the current contents of the TLB

### ***11.1.14 mipsTLBGetPhys***

Reports the entry(s) in the TLB that match the given virtual address and ASID

Table 17. mipsTLBGetPhys command arguments

Argument	Type	Description
-asid	Uns64	ASID
-va	Uns64	virtual address

### ***11.1.15 mipsWriteRegister***

Write to a processor register using <resource> <offset> <value>

Table 18. mipsWriteRegister command arguments

Argument	Type	Description
-offset	Int32	the register offset number
-resource	Int32	the register resource number
-value	Uns64	the register value to be written

### ***11.1.16 mipsWriteTLBEntry***

Writes values to a TLB entry using the index, lo0, lo1, hi0 and mask fields

Table 19. mipsWriteTLBEntry command arguments

Argument	Type	Description
-hi0	Uns64	the TLB entry high address
-index	Uns64	the TLB entry index
-lo0	Uns64	the TLB entry low address 0



-lo1	Uns64	the TLB entry low address 1
-mask	Uns64	the TLB entry mask

## 12 Registers

### 12.1 Level 1: CPU

#### 12.1.1 Core

Table 20. Registers at level 1, type: CPU, register group: 'Core'

Name	Bits	Initial value (Hex)		Description
zero	32	0	r-	constant zero
at	32	0	rw	
v0	32	0	rw	
v1	32	0	rw	
a0	32	0	rw	
a1	32	0	rw	
a2	32	0	rw	
a3	32	0	rw	
t0	32	0	rw	
t1	32	0	rw	
t2	32	0	rw	
t3	32	0	rw	
t4	32	0	rw	
t5	32	0	rw	
t6	32	0	rw	
t7	32	0	rw	
s0	32	0	rw	
s1	32	0	rw	
s2	32	0	rw	
s3	32	0	rw	
s4	32	0	rw	
s5	32	0	rw	
s6	32	0	rw	
s7	32	0	rw	
t8	32	0	rw	
t9	32	0	rw	
k0	32	0	rw	
k1	32	0	rw	
gp	32	0	rw	
sp	32	0	rw	stack pointer
s8	32	0	rw	frame pointer

ra	32	0	rw	
pc	32	bfc00000	rw	program counter

### 12.1.2 FPU

Table 21. Registers at level 1, type: CPU, register group: 'FPU'

Name	Bits	Initial value (Hex)		Description
f0	32	0	rw	
f1	32	0	rw	
f2	32	0	rw	
f3	32	0	rw	
f4	32	0	rw	
f5	32	0	rw	
f6	32	0	rw	
f7	32	0	rw	
f8	32	0	rw	
f9	32	0	rw	
f10	32	0	rw	
f11	32	0	rw	
f12	32	0	rw	
f13	32	0	rw	
f14	32	0	rw	
f15	32	0	rw	
f16	32	0	rw	
f17	32	0	rw	
f18	32	0	rw	
f19	32	0	rw	
f20	32	0	rw	
f21	32	0	rw	
f22	32	0	rw	
f23	32	0	rw	
f24	32	0	rw	
f25	32	0	rw	
f26	32	0	rw	
f27	32	0	rw	
f28	32	0	rw	
f29	32	0	rw	
f30	32	0	rw	
f31	32	0	rw	
fsr	32	0	rw	floating point status
fir	32	739600	r-	floating point information

### 12.1.3 DSP

Table 22. Registers at level 1, type: CPU, register group: 'DSP'

Name	Bits	Initial value (Hex)		Description
lo	32	0	rw	
hi	32	0	rw	
lo1	32	0	rw	
hi1	32	0	rw	
lo2	32	0	rw	
hi2	32	0	rw	
lo3	32	0	rw	
hi3	32	0	rw	
dspctl	32	0	rw	DSP control

### 12.1.4 COP0

Table 23. Registers at level 1, type: CPU, register group: 'COP0'

Name	Bits	Initial value (Hex)		Description
sr	32	400004	rw	CP0 register 12/0 (status)
bad	32	0	rw	CP0 register 8/0 (badvaaddr)
cause	32	0	rw	CP0 register 13/0 (cause)
index	32	0	rw	CP0 register 0/0
random	32	0	rw	CP0 register 1/0
entrylo0	32	0	rw	CP0 register 2/0
entrylo1	32	0	rw	CP0 register 3/0
context	32	0	rw	CP0 register 4/0
userlocal	32	0	rw	CP0 register 4/2
pagemask	32	0	rw	CP0 register 5/0
wired	32	0	rw	CP0 register 6/0
hwrena	32	0	rw	CP0 register 7/0
badvaddr	32	0	rw	CP0 register 8/0
count	32	0	rw	CP0 register 9/0
entryhi	32	0	rw	CP0 register 10/0
compare	32	0	rw	CP0 register 11/0
status	32	400004	rw	CP0 register 12/0
intctl	32	e0000000	rw	CP0 register 12/1
srsctl	32	0	rw	CP0 register 12/2
srsmap	32	0	rw	CP0 register 12/3
epc	32	0	rw	CP0 register 14/0
prid	32	19600	rw	CP0 register 15/0

ebase	32	80000000	rw	CP0 register 15/1
config	32	80048482	rw	CP0 register 16/0
config1	32	9e231187	rw	CP0 register 16/1
config2	32	80000000	rw	CP0 register 16/2
config3	32	2420	rw	CP0 register 16/3
config7	32	80000000	rw	CP0 register 16/7
debug	32	2018000	rw	CP0 register 23/0
depc	32	0	rw	CP0 register 24/0
errctl	32	0	rw	CP0 register 26/0
itaglo	32	0	rw	CP0 register 28/0
idatalo	32	0	rw	CP0 register 28/1
dtaglo	32	0	rw	CP0 register 28/2
ddatalo	32	0	rw	CP0 register 28/3
l23taglo	32	0	rw	CP0 register 28/4
l23datalo	32	0	rw	CP0 register 28/5
itaghi	32	0	rw	CP0 register 29/0
idatahi	32	0	rw	CP0 register 29/1
dtaghi	32	0	rw	CP0 register 29/2
l23datahi	32	0	rw	CP0 register 29/5
errorepc	32	0	rw	CP0 register 30/0
desave	32	0	rw	CP0 register 31/0

### 12.1.5 Integration\_support

Table 24. Registers at level 1, type: CPU, register group: 'Integration\_support'

Name	Bits	Initial value (Hex)		Description
stop	32	0	rw	write with non-zero to stop processor

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