

# Linker Reference Manual

*by*

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ASH WARE, Inc.

Version 3.01

6/8/2024

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ASH WARE Inc.



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# 1

## Command Line Options

Type the executable name with the -h command line parameter to generate a list of the available options.

```
ETEC_link.exe -h
```

The linker/optimizer has the following format:

```
ETEC_link.exe <ObjectFile1> <ObjectFile2> <options>
```

The <options> can be one or more of the following options.

| Setting  | Option | Default | Example |
|--|--------|---------|---------|
| Display Help<br>This option overrides all others and when it exists no linking is actually done. | -h     | Off     | -h      |
| Open Manual<br>Opens the electronic version of this Linker Reference Manual.                     | -man   | Off     | -man    |

## 1. Command Line Options

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| Setting   | Option  | De fault | Example      |
|---|---|----------|--------------|
| <p>Open a Specific Manual</p> <p>Opens an electronic version of the specified manual.</p> | <p>-man=&lt;MANUAL&gt;</p> <p>where MANUAL is one of the following:</p> <p>TOOLKIT: Toolkit User Manual.</p> <p>COMP: Compiler Reference Manual</p> <p>LINK: Linker Reference Manual.</p> <p>ASMFS: eTPU Assembler Reference Manual - 'Legacy' Syntax.</p> <p>ASMAW: eTPU Assembler Reference Manual - ASH WARE Syntax.</p> <p>ETPUSIM: Stand-Alone eTpu Simulator Reference Manual.</p> <p>MTDT: Common reference manual covering all simulator/debugger products EXCEPT the eTPU Stand-Alone simulator.</p> | Off      | -man=ETPUCIM |

| Setting   | Option   | Default | Example               |
|---|--|---------|-----------------------|
|   | LICENSE:<br>License reference manual   |         |                       |
| Display Version<br>Displays the tool name and version number and exits with a non-zero exit code without linking.                                   | -version   | Off     | -version              |
| Display Licensing Info<br>Outputs the licensing information for this tool.  | -license   | Off     | -license              |
| Console Message Verbosity<br>Control the verbosity of the linker message output.  | -verb=<N><br>where N can be in the range of 0 (no console output) to 9 (verbose message output).   | 5       | -verb=9               |
| Console Message Suppression<br>Suppress console messages by their type/class. Multiple types can be specified with multiple – verbSuppress options. | - verbSuppress=<TYPE><br>where TYPE can be:<br>BANNER : the ETEC version & copyright banner.<br>SUMMARY : the success/failure warning/error count summary line | Off     | -verbSuppress=SUMMARY |

## 1. Command Line Options

| Setting  | Option  | De fault | Example                          |
|--|---|----------|----------------------------------|
|  | <p>WARNING : all warning messages</p> <p>ERROR : all error messages (does not affect the tool exit code)</p> <p>INFO : all informational messages</p> |          |                                  |
| Disable a specific warning   | -warnDis=<ID><br>where ID is the warning's identification number.<br>Applies to both warning and informational messages.                              | Off      | -WarnDis=41065                   |
| Strictly treat warnings as errors<br><br>If a link warning is encountered, treat it as an error such that the link fails | -Strict   | Disabled | -Strict                          |
| Input File Options   |   |          |                                  |
| List of Object Files to link   | <ObjectFile1><br><ObjectFile2> ...<br><ObjectFileN>   | None     | etpuc_cam.eao<br>etpuc_crank.eao |
| System Configuration File (optional)   | - sysConfig=<FileName><br>> where FileName is   | None     | - sysConfig=MySystemCfg.SysCfg   |

| Setting   | Option  | Default | Example               |
|---|---|---------|-----------------------|
| Describes system configuration such as system clock frequency, which functions are running channels and their priority levels, etc. running on which channels and at which priority level. This is used to calculate the Worst Case Latency (WCL) based on the Worst Case Thread Length (WCTL). Results are displayed in the analyses file. | a file that describes the system configuration. |         |                       |
| Import Executable<br>Includes a .COD legacy file as part of the build.  | -Imp=<name.cod>                                 | None    | -Imp=Existing.cod     |
| Imported Executable Data<br>Amount of Data Memory in bytes to allocate for the imported legacy (.COD) file. This setting is mandatory when importing a .COD file.   | -ImpData=<Bytes>                                | None    | -ImpData=0x224        |
| Imported Executable Data End Free Space<br>When specified, this address indicates the end of the global address range available for locating global data from   | -ImpDataEnd=<byte address>                      | None    | -<br>ImpDataEnd=0x3F0 |

## 1. Command Line Options

| Setting   | Option   | De fault | Example  |
|---|----------|----------|----------|
| <p>ETEC-compiled code. The globally addressable address space in the eTPU runs from 0x0 through 0x400. Some .COD compilations locate global data both in low global memory and at high global memory, leaving a gap in between. It is in these cases that the use of -ImpDataEnd is required; for most .COD file imports it is not required. For example, if the imported .COD uses the 3-byte unit at 0x3FD as temporary storage, and uses up through 0x55 in low global memory, then the ideal linker options would be "- ImpData=0x58 - ImpDataEnd=0x3FC".</p> |          |          |          |
| <p>Disable Imported Executable Optimizations</p> <p>Optimizations on the imported legacy (.COD) executable file default to enabled. This option overrides the default such that optimizations are disabled for imported executables.</p>  | -ImpOpt- | Disabled | -ImpOpt- |

| Setting   | Option                  | Default  | Example                         |
|---|-------------------------|----------|---------------------------------|
| <p>Import a Code Image File</p> <p>Specify a code image file to be loaded into low code memory as part of the linking process.</p>  | -imageImport=<FileName> | None     | -imageImport=engine_A_set.image |
| <p>Disable Import of the Default Error Handling Library</p> <p>When this option is specified the default error handling library is not imported and the memory fill is 0 unless otherwise specified. Once disabled, users can provide their own error handlers using the error handler names (<code>_Error_handler_entry</code>, etc.).</p> | -ErrorLib-              | Enabled  | -ErrorLib-                      |
| Output File Options   |                         |          |                                 |
| <p>Output File To Produce</p> <p>Executable file name</p>   | -out=<BaseFileName>     | None     | -out=MyOutputFile               |
| <p>Suppress ELF/DWARF File Generation</p>   | -elf-                   | Generate |                                 |
| <p>Suppress Entry Table Debug Data</p> <p>Some consumers of ELF/DWARF files may</p>   | -etdbg-                 | Generate |                                 |

## 1. Command Line Options

| Setting  | Option   | De fault                          | Example       |
|--|--|-----------------------------------|---------------|
| not be compatible with the entry table debug data; this disables its output,   |  |                                   |               |
| <p>Output a global data segment in the ELF/DWARF file</p> <p>When this option is specified a global data segment is generated in the ELF/DWARF file. It has R/W attributes set, and an alignment of 4 bytes.</p>                     | -elfgd   | Do not output global data segment | -elfgd        |
| <p>Export the image in a re-linkable format</p> <p>This option is to be used if two independent images are being combined for use to run on eTPU engine A and engine B separately. Works with -imageImport.</p>                      | -imageExport   | None                              | -imageExport  |
| <p>Set the endian mode for auto-generated host code</p> <p>This option configures the endian-ness of auto-generated host code. This is a factor in non-32-bit location data, auto-struct, and any 8-bit initialized data or code</p> | <p>-endian=&lt;MODE&gt;</p> <p>where MODE can be:</p> <p>BIG : output code/data in big endian format (default)</p> | BIG                               | -endian=MULTI |

| Setting   | Option   | Default                  | Example                  |
|---|--|--------------------------|--------------------------|
| <p>data. The default big endian setting results in output no different from all previous releases, whereas the MULTI option outputs code/data in form that can support both types of endian host processors.</p>  | MULTI : output code/data in both big and little endian formats so that the code can be compiled to work with either big or little endian host processors |                          |                          |
| <p>Defines Header File To Produce</p> <p>A set of #defines used for host-side drivers. Defaults to the executable file name with ‘_defines’ appended to the base file name and a .h extension</p>   | -defines=<FileName>  | Based on executable name | -defines=MyDefinesFile.h |
| <p>Suppress Defines File Generation</p>   | -defines-  | Generate                 | -defines-                |
| <p>Global Mnemonic</p> <p>The specified mnemonic gets pre-pended to all names in the auto-generated header file and executable image array C file. This is useful when multiple images are to be used at host load time, thereby avoiding naming conflicts.</p> | -GM=<Text>   | '_'                      | -GM=_FS_                 |

## 1. Command Line Options

| Setting   | Option   | De fault                                    | Example                              |
|---|--|---|--------------------------------------|
| <p>Produce Auto-Struct Header File / Specify Name</p> <p>A set of structure declarations that can be used for host-side driver development. If no name is specified, it defaults to the executable file name with ‘_struct’ appended to the base file name and a .h extension</p> | <p>-autostruct // default (deprecated)</p> <p>- autostruct=&lt;FileName &gt;</p> <p>-autostruct- // disable auto-struct generation</p> | <p>auto-struct file generation</p>          | <p>- autostruct=etpu_if_struct.h</p> |
| <p>Produce Host Auto-Code Files</p> <p>For each eTPU class/function template host API files are auto-generated that include data structure and initialization templates. Works in conjunction with the auto-struct and auto-defines capability.</p>                               | <p>-awac</p>   | <p>Do not generate host auto-code files</p> | <p>-awac</p>                         |
| <p>Initialized Data File to Produce</p> <p>A set of data structures used to initialize global and channel-frame memory. Defaults to the executable file name with ‘_idata’ appended to the base file name and .c, .h extensions.</p>  | <p>-idata=&lt;FileName&gt;</p>   | <p>Based on executable name</p>             | <p>idata=MyInitDataFile.c</p>        |

| Setting  | Option  | Default                | Example                  |
|--|---|------------------------|--------------------------|
| Suppress IData File Generation   | -idata-   | Generate               | -idata-                  |
| SCM C File<br>C array of opcodes and entry table data to be included on the host-side and copied into the eTPU's SCM. Defaults to the executable file name with '_scm' appended to the base file name and a .c extension | -scm=<FileName>   | None                   | -scm=MyScmFile.c         |
| Suppress SCM C file generation   | -scm-   | Generate               | -scm-                    |
| Data Size 8-bit Override<br>By default, scm and idata data is 32-bit; this option overrides and results in 8-bit initialized array output  | -data8  | 32-bit data            | -data8                   |
| Name of the analyses file to produce. Defaults to the executable file name with '_ana' appended to the base file name and an .html extension.  | -ana=<FileName><br>where FileName is the name of the analyses file to product | OutputFileBaseName.ana | -Ana=MyOverridenName.ana |
| Disable analysis file generation   | -ana-   | Enabled                | -ana-                    |
| Generate .lst files  | -lst  | Disabled               | -lst                     |

## 1. Command Line Options

| Setting   | Option  | De fault        | Example                                    |
|---|---|-----------------|--|
| <p>When specified, each source file that contributes to code generation is output into a list file with intermixed disassembly information. They are named the same as the source file but with a .lst extension. When just "-lst" is used, the list files are placed in the executable output path. When "-lstInSrc" is used each individual list file is output in the directory that corresponds to its source file. Last, the default executable output path for list files can be overridden by specifying a path with the "-lst=&lt;DirName&gt;" option form.</p> <p>"-lstaddr-" removes the address and opcode listings which puts the listing files into a format that is ideal for "diff." This is particularly helpful when comparing generated code for different compiler versions.</p> | <p>-lstInSrc</p> <p>-lst=&lt;DirName&gt;</p> <p>-lstaddr-</p> |                 | <p>-lstInSrc</p> <p>-lst=..\ListFiles\</p> |
| <p>Generate .map file / Specify Name</p>  | <p>-map</p>   | <p>Disabled</p> | <p>-map</p>                                |

| Setting  | Option                             | Default   | Example                            |
|--|------------------------------------|---|------------------------------------|
| <p>When specified, a map file containing code &amp; data location information is output. The default name is the executable name appended with a ".map" extension, in the executable output path. The path and name can be overridden using the "<code>=&lt;FileName&gt;</code>" option.</p>   | <code>-map=&lt;FileName&gt;</code> |   | <code>-map=..\myMapFile.map</code> |
| <p>Suppress inclusion of scratchpad and stack in pragma write global data initialization pragmas</p> <p>By default (V3.00B and newer) any global scratchpad and stack space will be included with the pragma write global data initialization (<code>::ETPUglobalimage[32]</code> and <code>::ETPUglobalinit[32]</code>) output. This is done because the sizing of these outputs is often used in host initialization code to set the start of the channel frame allocation area. Specifying this option turns off the addition of scratchpad and stack to the global data initialization output.</p> | <code>-ssdata-</code>              | Include scratchpad and stack in initialization data | <code>-ssdata-</code>              |

## 1. Command Line Options

| Setting   | Option  | De fault  | Example           |
|---|---|---|-------------------|
| <b>Code Generation Options</b>  |   |   |                   |
| <p>Target Selection</p> <p>Select the destination processor for the compilation.</p>  | <p>-target=&lt;TARGET&gt;</p> <p>where TARGET can be:</p> <p>ETPU1 : compile for the baseline eTPU processor.</p> <p>ETPU2 : compile for the eTPU2 processor version.</p> | ETPU1   | -target=ETPU2     |
| <p>Entry Table Base Address</p> <p>Underlying architecture supports only multiples of 0x800</p>   | -etba=<Addr>  | 0x0   | -etba=0x800       |
| <p>SCM Code Size</p>  | -CodeSize=<Bytes>   | 0x1800 (6K)   | -CodeSize=0x4000  |
| <p>Error Handling Library Fill Disable</p> <p>This option should be used when the user wants the off SCM and unused thread handlers to be part of the build, but also wants the minimal image size.</p> | -ErrorFill-   | Fill all of SCM with invalid entry / in weeds handler values. | -ErrorFill-       |
| <p>Fill Opcode Override</p> <p>Use specified opcode to fill any unused SCM code space. Overrides</p>  | -FillOpcode=<Val>   | Jump to error library   | -FillOpcode=0x123 |

| Setting   | Option                              | Default | Example                           |
|---|-------------------------------------|---------|-----------------------------------|
| the error library fill and the -ErrorFill- option.  |                                     |         |                                   |
| Disable optimizations<br>Optimizations default to enabled. This option overrides the default such that optimizations are disabled.  | -opt-                               | Enabled | -opt-                             |
| Network License Options   |                                     |         |                                   |
| Retry Network License<br>If unable to acquire a full license from the network license server, the application will continue to re-try periodically up to the specified number of seconds until it succeeds, or the retry time expires.          | -networkRetry=<N>                   | Off     | -networkRetry=600                 |
| Check-out Network License<br>Attempts to check-out a network license until the specified date and time. The HH field is in 24 hour time. No linking is done, only the license check-out. An exit code of 0 indicates success, non-zero failure. | -networkCheckout=<YYYY:MM:DD:HH:MM> | Off     | -networkCheckout=2010:08:04:18:00 |
| Check-in Network License  | -networkCheckin                     | Off     | -networkCheckin                   |

## 1. Command Line Options

---

| Setting  | Option | Default | Example |
|--|--------|---------|---------|
| Returns a checked out license to the network license server. This only needs to be done if the license is being returned before its checkout expiration date. No linking is done. An exit code of 0 indicates success, non-zero failure. |        |         |         |

# 2

## Code Location

There is almost no reason at all for the user to care about code location so this section is kind of like describing the difference between blue and red to a color blind person. Having said that, code gets located beginning at address zero and continues upward.

The big issues are the entry table and “unbreakable code chunks”. An “unbreakable code chunk” is a section of code that must remain contiguous in order to function properly and the definition of “functioning properly” varies between the compiler and assembler. Entry table locating is done first followed by code locating. If an “unbreakable code chunk” would over-write the entry table, then it is moved in its entirety to the first available opcode slot after the entry table.

ASH WARE reserves the right to change this algorithm, but in any case if you are doing something that depends on the locating algorithm, then this author suspects you are doing something wrong.

### 2.1 Code Size

Although the eTPU has a code space of 64K bytes, the various microcontrollers only populate a portion of this. For instance, some eTPU derivatives in the Coldfire family populate 6K bytes and some eTPU derivatives in the MPC55xx family populate 12K.

To accommodate this variation in code size between the different eTPU derivatives there is a command line argument for specifying the amount of code space actually populated.

## 2. Code Location

---

This code size must be aligned to a 2K boundary, and must be between 2K and the maximum code space allowed by the eTPU instruction set which is 64K.

# 3

## Global Error Handling

A variety of causes including alpha particles, coding errors, and silicon defects could cause eTPU code to execute in un-intended ways. The key issues to consider are error detection and error correction.

Undetected errors are the bane of electronic reliability because the probability of their presence accumulates over time, code size, hours spent coding, etc. Therefore ETEC places primary emphasis on error detection and has built in hooks for detection of many errors.

Error correction, on the other hand, is considered to be in the user's domain and ASH WARE strongly recommends that each system designer carefully design their systems with error correction strategies in place. Having said that, ETEC does support "default" error correction mechanisms. If these default mechanisms are not overridden, they will correct a variety of detected error cases. The default error handling mechanism is disabled or overridden by using the `-ErrorLib-` linker command line option.

ASH WARE recommends that users create specially-named error handlers for a variety of possible error scenarios. These handlers are generally written in assembly, and have the following names.

```
\_Error\_handler\_entry.  
\_Error\_handler\_scm\_off\_weeds  
\_Error\_handler\_fill\_weeds  
\_Error\_handler\_unexpected\_thread
```

### 3. Global Error Handling

---

These error handlers should be used to correct the error conditions described later in this section.

#### 3.1 Global Error Data

If an error is detected, information helpful in diagnosing the source of the error is placed in an automatically-generated global variable named as follows:

`\_Global\_error\_data.`

This 32-bit variable is used to encode error information as shown in the following table.

|      |    |    |    |    |    |    |      |    |    |       |    |      |    |    |    |
|------|----|----|----|----|----|----|------|----|----|-------|----|------|----|----|----|
| 31   | 30 | 29 | 28 | 27 | 26 | 25 | 24   | 23 | 22 | 21    | 20 | 19   | 18 | 17 | 16 |
| EESB |    |    |    |    |    |    |      |    |    | Spare |    |      |    |    |    |
|      |    |    |    |    |    |    |      |    |    |       |    |      |    |    |    |
| 15   | 14 | 13 | 12 | 11 | 10 | 9  | 8    | 7  | 6  | 5     | 4  | 3    | 2  | 1  | 0  |
| EEVS |    |    |    |    |    |    | EECL |    |    |       |    | EECN |    |    |    |

##### **EESB – Encoded Error Source Bits**

Bit = 1 indicates that such an error has been detected

Bit = 0 indicates that such an error has not been detected.

Bit 31 indicates that `_Error_handler_entry` has executed.

Bit 30 indicates that `_Error_handler_scm_off_weeds` has executed.

Bit 29 indicates that `_Error_handler_fill_weeds` has executed.

Bit 28 indicates that `_Error_handler_unexpected_thread` has executed

Bit 27-22 set aside for user-defined errors (custom extension of error handler)

##### **EEVS – Encoded Event States**

Bit = 1 indicates that an event is active

Bit = 0 indicates that an event is not active

Bit 15 contains the LINK state

Bit 14 contains the Transition B state

- Bit 13 contains the Transition A state
- Bit 12 contains the Match B state
- Bit 11 contains the Match A state
- Bit 10 contains zero (future expansion)
- Bit 9 contains zero (future expansion)

#### **EECL – Encoded Error Conditionals**

- Bit 8 contains the sampled input pin state
- Bit 7 contains the current output pin state
- Bit 6 contains the flag 1 state, if available (eTPU2)
- Bit 5 contains the flag 0 state, if available (eTPU2)

#### **EECN - Encoded Error Channel Number**

This is the active channel number of the last event handler. New incoming event handlers overwrite this value such that if error handlers are executed multiple times, then the number contains the last-executed time.

When an error the above error data is written to `_Global_error_data`, all service latches are cleared, and the thread exits. In general, for the error handler to be truly useful for a user, it should be enhanced to issue the microcode global exception, which can trigger the host global exception handler to execute if the interrupt has been enabled - see specific microcontroller documentation for details. This interrupt handler can decode the error data and take an appropriate actions, such as shutting down a channel or eTPU module. The easiest way to do this is to start from the default handler source code and add the global exception, bringing this new file into the build, and disabling the default via the `-ErrorLib-linker` option.

## **3.2 Error Handling Library**

The ASH WARE defined error handlers are defined in a library named `"_global_error_handler.lib"` (for eTPU1) and `"_global_error_handler_etpu2.lib"` (for eTPU2) which is provided as part of ETEC. The linker automatically includes one of these two libraries based on whether the linker is building for eTPU1 or eTPU2.

The error handling library can be disabled from being included in the linking process via the `-ErrorLib-` command line option.

### 3.3 Invalid Entry Error Handling

Threads get executed based on pointers found in the entry table. The entry table supports up to 32 functions but it is rare to actually use all 32 functions. The unused entries are considered to be invalid and in normal operation would never get accessed.

It is an error to access an unused function in the entry table. When possible, unused entries are filled with the following address.

`\_Error\_handler\_entry.`

It is not always possible to fill unused entries with this address because unused portions of the entry table can be used to hold code. So this address is used where the entry table contains neither eTPU functions nor eTPU code.

### 3.4 In the SCM OFF Weeds Error Handling

The address space of the eTPU is 64K, but NXP generally only fills a very small portion of this code space with physical memory. For example, the very first MPC5554 version had only 12K of code memory. So what happens if, due to an error, the thread of execution should occur in the unused 52K of code space?

It is an error to execute from the unused portion of the SCM code memory and when this happens the actual opcode that gets executed is specified by the SCMDATAOFFR register. ETEC provides an SCMDATAOFFR register value (see the `SCM_OFF_OPCODE` #define in the auto-defines header section) that will cause the following error handler to execute.

`\_Error\_handler\_scm\_off\_weeds`

Note that this error handler will only execute if the #define `SCM_OFF_OPCODE <value>` provided in the automatically-generated header file is used to program the `ETPUSCMOFFDATAR` register.

### 3.5 In the FILL Weeds Error Handling

Say you have 18K of available code memory but use only 15K. The remaining 3K of code memory is essentially spare capacity. So what happens if the thread of execution somehow moves to this extra 3K of code memory?

It is an error to execute from this spare memory. ETEC defaults to filling this spare memory with a jump to the error handler listed below. Note that a jump is used instead of a call so that the user can possibly determine an address (based on the return address register, RAR) of any possible originating return that might have caused this code to get executed in the first place.

#### `_Error_handler_fill_weeds`

A related issue is the fill opcode specified on the command line. If a fill-opcode value is specified on the command line then this overrides the default fill opcode that ETEC would have used to jump to this error handler. It is therefore an error to both specify a fill opcode and to override this error handler, and in fact if a fill opcode is specified then ETEC will neither provide, nor allow, this error handler to exist.

## 3.6 Unexpected Thread Error Handling

Say you have a function that does not support an incoming link event. If a link does occur this is an error condition and should be made observable to the host software so that the problem does not remain undetected. The 'Unexpected Thread' error handler can be used both in ETEC mode and legacy mode 'C' as well to detect these types of unexpected errors. Note that no overhead is incurred using the methods described below. The address of the error handler is injected directly into the entry table.

In ETEC mode simply add the following to any unused entries.

```
< . . . >
5 | x | x | x | input=x | x | x | low | enable | ::_Error_handler_unexpected_thread
< . . . >
```

In Legacy mode call the `_Error_handler_unexpected_thread` as a fragment from any unused threads. For example, the following could be done if HSR is not used:

```
if( hsr==1 )
{
    // Call the error handler as if a fragment
    // The address will be injected
    // directly into the entry table
    // thereby incurring no overhead
    _Error_handler_unexpected_thread();
}
```

The most typical place to reference this error thread would be in the final "else" catch-all clause:

```
// ...
```

### 3. Global Error Handling

---

```
else
{
    _Error_handler_unexpected_thread();
}
```

In the assemble entry table place the unexpected thread error handler directly in the table as follows.

```
hsr | lsr | transitionB | transitionA | pin | flag1 | flag0 | load | matches |
1 | X | X | X | input=0 | X | 0 | low | enable |
::_Error_handler_unexpected_thread
```

## 3.7 Extending the Error Handler

It is possible to extend the custom error handler in assembly by adding assembly code that uses 'user-defined' error bits to extend the error library. Care must be taken to use error bits set aside for the user, and not those set aside for future extension.

Note that the existing error library is accessed by jumping to label '\_Error\_handler\_save\_states'. When entering this location the P\_31\_0 register contains the error bits that the user wishes to set.

```
// File: UserErrorHandler.sta

// declare the external error handler data bit that will be
set
extern int32 _Global_error_data;

_Error_handler_user:

    // Set user-defined error bit 2
    // and leave it in p_31_24
    ram p_31_0 = _Global_error_data;;
    seq goto _Error_handler_save_states;;
    alu p_31_24 = p_31_24 | 0x1;; // Set user-defined
error 2
```

## 3.8 Accessing the Error Handler

It is possible to access the existing error handler library in both 'ETEC' as well as 'Legacy' mode.

To access the factory-supplied error handlers directly in either mode, they are called suchly

```
// Link service requests are not supported
// Make this error observable by calling a factory-defined
error handler
if ( IsLinkServiceRequestEvent() )
{
    // Error Detected,
    // the ETEC global error handler in etpuc mode
    _Error_handler_entry();
}

```

Note that the three factory-defined error handlers are defined in factory-provided header file 'ETpu\_Lib' as follows

```
_eTPU_thread _Error_handler_entry(_eTPU_matches_enabled);
_eTPU_thread
_Error_handler_scm_off_weeds(_eTPU_matches_enabled);
_eTPU_thread
_Error_handler_fill_weeds(_eTPU_matches_enabled);

```

To access a user-defined error handler from 'C' that was written in assembly, the error handler must be declared as a fragment as follows.

```
_eTPU_thread _Error_handler_user(_eTPU_matches_enabled);

```

In ETEC mode these factory-defined and user-defined error handlers can also be directly injected into the event vector table as follows.

```
DEFINE_ENTRY_TABLE(TestClass, TestClass, standard,
inputpin, autocfsr)
{
    //          HSR LSR M1 M2 PIN F0 F1 vector
    ETPU_VECTOR1(1,  x,  x,  x,  x,  0,  0,  x,
_Error_handler_user),
    <... SNIP ...>
    ETPU_VECTOR1(5,  x,  x,  x,  x,  x,  x,  x,
_Error_handler_user ),
    ETPU_VECTOR1(6,  x,  x,  x,  x,  x,  x,  x,
_Error_handler_entry ),
    ETPU_VECTOR1(7,  x,  x,  x,  x,  x,  x,  x, MyThread),

```

### 3. Global Error Handling

---

```
ETPU_VECTOR1(0, 1, 1, 1, x, 0, x,  
_Error_handler_user),  
    <... SNIP ...>  
ETPU_VECTOR1(0, 1, 1, 0, x, 1, x,  
_Error_handler_user),  
};
```

## 3.9 Creating a User-Defined Error Handler

A user defined error handler can be defined using a fragment. Use of a fragment is an efficient method because a fragment reduces (and in this case eliminates) the call/return overhead. From within the thread, simply call the fragment as follows.

```
// Declare the global error handler as a fragment  
// to eliminate the call/return overhead  
_eTPU_fragment Global_Error_Func()  
{  
    int l_error = chan;  
    if (LinkServiceRequest == 1) l_error+=0x0100;  
    if (MatchALatch == 1) l_error+=0x0200;  
    if (MatchBLatch == 1) l_error+=0x0400;  
    if (TransitionALatch == 1) l_error+=0x0800;  
    if (TransitionBLatch == 1) l_error+=0x1000;  
    Global_Error = l_error;  
    ClearAllLatches();  
}  
  
// Legacy mode function that accesses the user-defined  
// error handler  
if ( IsLinkServiceRequestEvent() )  
{  
    // Test accessing  
    // a user error handler in etpuc mode  
    Global_Error_Func();  
}
```

In ETEC mode, a user-defined global error handler is declared as a thread, then inserted directly into the event vector table as follows.

```
// Get a pointer to the global error handler data  
extern int _Global_error_data;  
  
_eTPU_thread MyGlobalErrorHandler(_eTPU_matches_enabled)
```

```
{
    // Set bit 22, this is user-defined error #2
    _Global_error_data |= (1<<22);
}

// Set one or more invalid entries to point the the user-
defined error handler
DEFINE_ENTRY_TABLE(TestClass, TestClass, standard,
inputpin, autocfsr)
{
    //          HSR LSR M1 M2 PIN F0 F1 vector
    <... SNIP ...>
    ETPU_VECTOR1(0, 1, 1, 1, x, 0, x,
MyGlobalErrorHandler),
    <... SNIP ...>
};
```

The other way to create a custom handler is to disable import of the default with the `-ErrorLib-` linker option, but include in the link error handling code that declares the 3 key labels: `_Error_handler_entry`, `_Error_handler_scm_off_weeds`, and `_Error_handler_fill_weeds`.



# 4

## Entry Table

This section covers the entry table.

### 4.1 Entry Table Base Address assignment

There is a command line argument for specifying the entry table base address. The eTPU architecture forces the entry table base address to be on a 2K boundary. Additionally, the entire entry table must be located within the boundaries of the amount of code actually populated in the eTPU derivate.

### 4.2 CFSR Assignment

Each entry table is assigned a CFSR register value. Although this can be done by the user in the compiler and assembler, it is generally preferable to allow the linker to assign CFSR values.

This section describes how un-assigned CFSR values are assigned. Although this section might seem interesting, especially to those who enjoyed the math portion of the SAT, specifics of this algorithm should not be counted on by the user. In fact, ASH WARE reserves the right to change this algorithm with future linker releases. Use the auto-defines capability to determine which CFSR value the linker has actually assigned to each entry table.

## 4. Entry Table

---

The linker assigns un-assigned CFSR values using the algorithms described here. The specific algorithm used depends on whether or not the entry table base address is at address zero (the default) and if there are any user-assigned CFSR values. The intent of this algorithm is to reduce the number and size of gaps in the entry table, thereby improving the code packing efficiency.

If the entry table is located at address zero and there are no user-assigned CFSR values then CFSR assignment begins with zero, and continues with progressively higher numbered values.

If the entry table is NOT located at zero and there are no user-assigned CFSR values then assignment begins with 31, and continues with progressively lower numbered values.

If the entry table is located at address zero but there are user-assigned CFSR values, then the linker assigns CFSR values starting with the highest numbered value, and assigns progressively lower numbered values until zero is reached. Then progressively higher numbered values are assigned

If the entry table is NOT located at zero and there ARE user-assigned CFSR values, then CFSR values assignment begins with the lowest user-assigned CFSR value and continues upwards to 31. Then progressively lower numbered values are assigned

# 5

## System Configuration Analyses

A system configuration file supports advanced analyses of the generated eTPU code in an actual system. System parameters such as system clock speed, channel priorities, and channel assigned functions are specified. Results are displayed in the analyses. file.

### 5.1 System Configuration File

The system configuration file is a text file that the user edits to specify the system configuration. The linker uses the information contained in this file along with the functional parameters in the code to determine things such as Worst Case Latency for a channel.

The file is specified on the command line using the `-sysConfig=<FileName>`.

The format is line based which each line may contain a single setting, or a comment.

#### **Ram Collision Rate**

`<PERCENT> RCR`

The ram collision rate is specified by the collision rate, in percent (0 to 100.)

#### **Clock Frequency**

`<FREQUENCY> mhz`

System clock frequency in megahertz.

## 5. System Configuration Analyses

---

### Processor Family

`<PROCESSOR_FAMILY>`

Processor family. Valid values are MCF (Coldfire,) MPC (NXP Power Architecture,) or SPC (STMicro Power Architecture.) Note that the NXP and STMicro power architectures both take two system clocks to execute one eTPU instruction. In the Coldfire architecture each eTPU instruction takes four system clocks to execute, OUCH!

### Channel Configuration

`<Engine> <CHANNEL> <FUNCTION> <PRIORITY> <MAX_WCTL>`

ENGINE is the engine of the channel being specified, valid values are A and B.

CHANNEL is the channel number being specified, valid range is 0 to 31.

FUNCTION is the name of the eTPU Function for legacy style code or the name of the eTPU Class for ETEC style code.

PRIORITY is the priority assigned to that channel. Valid values are 'high;', 'middle' and 'low'.

MAX\_WCTL is an optional parameter that specifies that maximum allowed Worst Case Thread Length (WCTL) in micro-seconds. The link will fail if the calculated WCTL exceeds this specified maximum.

### Comments

`// This is an example C style comment`

Comment lines using a leading double slashes. Empty lines are also treated as comments.

### Example System Configuration File

The following is an example of a system configuration file.

```
25   RCR   // RAM collision rate (percent)
133  mhz   // System clock frequency
MPC           // NXP Power Architecture

// - In engine A, the LOW priority is longer than the
MIDDLE
//   So latency is 1 low + 1 high (shorter MIDDLE not
used)
// Engine Channel Function Priority MaxWCL
(microseconds)
      A,      3,      UART,    high,      0.95
      A,      4,      PWM,     middle,
      A,      5,      PWM,     low,
```

```
// - In engine A, the LOW priority is longer than the
MIDDLE
// So latency is 1 low + 1 high (shorter MIDDLE not
used)
// Engine Channel Function Priority MaxWCL
(microseconds)
      B,      3,      QOM,      high,      1.40
      B,      4,      UART,      middle,
      B,      5,      UART,      low,
```

The linker generates the following information in the analyses file based on the System Configuration file listed above.

### Worst Case Latency

| Channel/Function          | Priority | WCTL*              | Max WCL | Actual WCL           |
|---------------------------|----------|--------------------|---------|----------------------|
| Engine A, Channel 3, UART | High     | 0.56 us<br>(30,14) | 0.95 us | 0.86 us<br>(45,20)   |
| Engine A, Channel 4, PWM  | Middle   | 0.30 us<br>(15,6)  | -       | 1.97 us<br>(105,48)  |
| Engine A, Channel 5, PWM  | Low      | 0.30 us<br>(15,6)  | -       | 3.64 us<br>(195,90)  |
| Engine B, Channel 3, QOM  | High     | 0.76 us<br>(43,17) | 1.40 us | 1.32 us<br>(73,31)   |
| Engine B, Channel 4, UART | Middle   | 0.56 us<br>(30,14) | -       | 2.85 us<br>(159,65)  |
| Engine B, Channel 5, UART | Low      | 0.56 us<br>(30,14) | -       | 5.14 us<br>(288,116) |

## 5. System Configuration Analyses

---

Note: WCTL (Worst Case Thread Length) includes the Steps, RAM's, TST's (Time Slot Transitions) and TST-RAM's with RCR (RAM Collision Rate) factored in. The two numbers in parantheses are the instruction-steps and the RAM's

### Configuration

- System clock frequency: 133 MHz
- Ram Collision Rate (RCR): 25%
- Processor family: 'NXP Power Architecture'

# 6

## Channel Hardware Instruction Packing

This section describes the most important improvement of this tools suite over other options and the capabilities described are the primary motivating factor behind the development of this compiler (that and income of course.) Consider the following sub-instructions.

```
chan clear MatchRecognitionLatchA;;  
chan matchA = ertA, set MatchEnableLatchA;;
```

It turns out that the parallel nature of the eTPU's instruction set allows these sub-instructions to be packed into a single opcode. But it is also possible that these sub-instructions could be placed into separate opcodes and the trouble is that the eTPU's channel hardware behavior is vastly different depending on which way the optimizer packs these sub-instructions. The combination of lack of control and lack of documentation has driven this author into a state of apoplectic perdition for the last several years.

ETEC addresses this issue in two ways, one is really good (user-control), and one is, well, kinda good (Convention Documentation.) These are described in the following two sections.

### 6.1 Channel Hardware Sub-Instruction Packing Convention

The channel hardware sub-instruction packing convention documented in this section is the default for the ETEC compiler. This packing convention is based on ASH WARE's understanding of the legacy compiler.

## 6. Channel Hardware Instruction Packing

---

The legacy compiler packed channel hardware sub-instructions based on an (apparently) un-documented convention. That is to say, the packing scheme was (apparently) not documented, but the convention would (presumably) stay the same from one release to the next such that code that functioned in a particular way in one release would retain that same functionality if built using a different compiler release.

The ETEC packing convention can be disabled using the `#pragma no_packing_convention` and, in fact, the author recommends disabling the packing convention and instead explicitly specifying the packing constraints as described in section 5.1, “Sub-Instruction Packing Control.” Explicitly specifying the packing constraints both reduces code size and increases your own understanding of the quality-critical issues associated with channel hardware sub-instruction ordering.

Channel sub-instructions that are located adjacently in source code are packed together. This definition is ambiguous, and requires further description. To see that the definition is ambiguous, consider the following three sub-instructions.

```
Sub Instruction A;;  
Sub Instruction B;;  
Sub Instruction C;;
```

Consider the case where A, B, and C cannot fit into a single opcode, but A and B can fit together, and B and C can fit together as well. Either of the following two packing combinations satisfy the over-simplified packing convention as described up to this point.

```
Opcode 1:  Sub Instruction A + Sub Instruction B;;  
Opcode 2:  Sub Instruction C;;
```

Or, ...

```
Opcode 1:  Sub Instruction A;;  
Opcode 2:  Sub Instruction B + Sub Instruction C;;
```

Therefore, the packing definition is ambiguous and requires further description.

Starting from the top of the source code (lowest line number) and working towards the bottom of the file, channel hardware sub-instructions are packed into opcodes. When a sub-instruction is encountered that will not fit into the opcode being packed, then a new opcode is generated and newly-encountered sub-instructions are packed into this newly-generated opcode.

This packing convention only applies to channel hardware sub-instructions and only to those sub instructions with ordering dependencies. The following sub-instruction fields are specifically excluded: FLC and CIRC.

These packed opcodes may experience some movement (to reduce code size) but in all cases the movement will not result in any functional variation except as noted elsewhere in the documentation.

With this fully-defined description, ONLY the following packing order can occur.

```
Opcode 1:  Sub Instruction A + Sub Instruction B;;  
Opcode 2:  Sub Instruction C;;
```

To summarize, the key points presented in this section are as follows:

- For optimal quality, reduced code size, and full understanding of your code's behavior, it is best to disable the packing convention described in this section, and instead fully specify the packing order as described in the section 5.1, "Sub-Instruction Packing Control."
- The packing convention defined in this section has been adopted to maximize backward compatibility with the legacy compiler. The author recommends not relying on the legacy packing convention.
- The legacy packing convention applies ONLY to channel hardware sub-instructions.



# 7

## Channel HW Sub-Instruction Re-Ordering

The CIRC field is considered to be independent of all other channel hardware fields. It can be re-ordered with no restrictions. It is restricted relative to RAM operations though. It cannot pass any RAM operations. Once in the same instruction as a RAM, it cannot be re-ordered.

The FLC field has no re-ordering restrictions whatsoever.

The LSR field has no re-ordering restrictions whatsoever. (It is tied to the TST channel, not the channel register)

MRL and ERW form “blocks” relative to the following fields; OPAC, IPAC, TDL, TBS, PSC, PSCS, MRLE, PDCM, PDCM, and MTD. If MRL and ERW are upstream, then they cannot join with these fields. Conversely, if these fields are upstream then they CAN join with these fields.



# 8

## Linking Legacy (.COD) Code

ETEC supports linking existing legacy mode eTPU code (.COD) along with object files generated by the ETEC tools chain (assembly and “C” source.) This capability allows users to migrate to the ETEC tools suite in a gradual manner.

### 8.1 Legacy Global Memory Allocation

Global memory is normally associated with global variables but the legacy compiler also uses global memory to store values across function calls, to pass function call variables, and for dynamic local variables that overflow the register set.

The issue (unfortunately) is that there is no reliable way of determining the amount of global memory that is used by the legacy compiler, and ETEC (unfortunately) requires that you pass this value to the ETEC linker via the command line (-ImpData). In fact, global memory allocation is even more complicated than that in some cases because at times a .COD compilation also uses high global memory just below address 0x400, typically for temporary storage. When this split global locating occurs in the .COD file to imported, the *lower* bound of this upper section of data must also be specified (-ImpDataEnd). This allows ETEC to safely locate its global variables from ETEC-compiled object files into the empty range. See the command line options section for a description of how to specify the amount of global memory to allocate for legacy compiler generated (.COD) code.

### 8.2 Disabling optimization on legacy code

Optimizations on legacy code default to enabled. When enabled the entry table will likely change to adjust address pointers to the size-reduced code and to optimize preloads. Opcodes may change some due to optimization, though unchanged opcodes will have a bias toward retention of their original packing.

Optimizations for the imported legacy code (.COD) can be disabled, see the command line options for a description of how this is done. With optimizations disabled the entry table and executable portions of the code image remain unchanged, though any “dead space” between the entry table and code will use the ETEC fill algorithm.

The ETEC optimizer makes assumptions about code behavior and certain legacy-compiler features may violate these assumptions such that the ETEC optimizer should not be enabled legacy-compiler generated code. The following is a list of the known features

- \* Register allocation to global or static variables. (The ETEC optimizer assumes that registers need not retain their value across threads.)

### 8.3 Legacy Code Limitations

The following restrictions apply to the legacy compiler generated code.

- \* The entry table must be located at address zero (the normal default)
- \* Only COD compiler versions (TBD) are supported.
- \* Enabling of optimizations for legacy-generated code may invalidate any legacy auto-generated code.
- \* The .COD's fill opcode is ignored and the ETEC fill algorithm is used instead.

### 8.4 Legacy Restrictions on ETEC

Linking with legacy compiler generated code places some restrictions on the ETEC generated code that can be linked.

- \* The entry table must be located at address zero
- \* ETEC-generated code cannot specify a function number that is used by the legacy-compiler generated code.
- \* There must be a gap between the end of the legacy generated entry table and the start of legacy-generated code into which the ETEC-generated entry table gets placed (TBD: Can we relocate the BC-generated code??)

When compiling the legacy code, use the legacy “org” statement to generate this gap.

### 8.5 Legacy/ETEC Interactions

Some interactions between the legacy compiler generated code and ETEC generated code are allowed, as listed below.

Certain types of (generally simple) global variables declared in legacy-generated code can be accessed by ETEC generated code. These include the following

- \* int24, unsigned int24, int8, unsigned int8, int32, unsigned int32 (global)
- \* int, unsigned int, char, unsigned char.

### 8.6 Legacy/ETEC Misc Notes

- \* Analyses files are valid for etec generated code
- \* Disable optimizations on the legacy-generated code to retain validity of certain legacy #pragma writes (auto header)
- \* In many cases the legacy code’s
- \* The ETEC-generated auto-defines file is valid. In certain cases, the legacy-generated auto-header must not be used. For example the

### 8.7 Auto-Header and Auto-Defines Information Validity

Auto-header files are generated by the legacy compiler and auto-defines files are generated by the ETEC compiler. In all cases, information in the ETEC-generated auto-defines file is valid. The safest route is simply to switch to the ETEC-generated auto-defines file, but this may not be an option for all customers. This section describes which information from the legacy-generated auto-header can still be used.

Information in the legacy-generated auto-header may or may not be valid depending on the nature of the information and on whether or not optimizations are enabled for the legacy generated code.

## 8. Linking Legacy (.COD) Code

---

### 8.7.1 Invalid Legacy Auto-Header Information

The following list represents information in the legacy-generated auto header that are not valid.

- \* [The code block](#)
- \* [MISC value](#)
- \* [Global Data Size](#)

### 8.7.2 Supported ETPU\_C Compiler Versions

The following is a list of supported versions at the time of this printing. See our website for the most up-to-date list.

- \* [1.0.7.55](#)

Note that unsupported compiler versions will in all likelihood still work. If the version of the compiler that you are using is not on the supported versions list, please contact ASH WARE for support of your compiler version.

### 8.7.3 Qualifying Unsupported eTPU\_C Versions

Although code generated by unsupported eTPU\_C compiler versions will generally function when imported, it is possible to qualify unsupported versions using the process described in this section.

The key issue in the qualification process is that not all eTPU\_C compiler versions are available to ASH WARE. Therefore, to qualify your eTPU\_C compiler version, the following process has been established. (TODO=develop a standard test suite)

- Customer requests ASH WARE to support a specific eTPU\_C compiler version.
- ASH WARE provides customer with a test build suite
- Customer builds the test suite and provides ASH WARE with the resulting .COD file.
- ASH WARE adds the .COD file to the ETEC test suite and (assuming it passes all tests) adds this .COD version to the list of supported compilers.

## 9

## Linking Imported Code Image

This capability allows two independent eTPU code images to be located together in one final image to be loaded into an eTPU module. This is a capability that would be rarely needed, but does allow for total independence between code running on eTPU engine A and code running on eTPU engine B, as each image has its own entry table. The code image that is to occupy the lower slice of code memory (and thus also the lower slice of global and engine data space) must be generated first, with the code image generated by the "-imageExport" linker option. Its total size should be carefully managed either by setting the SCM size much smaller, or by not using the default error handling library (-ErrorLib-), or disabling error fill (-ErrorFill-). The second build, which will be located after the code/data space utilized by the first image, imports that image via the "-imageImport" linker option. The entry table for the second build must be placed above the imported code image. E.g. if the imported code image is 0x1800 bytes, the entry table is best placed at address 0x1800. The output of this second build will contain the first image, and the calculated MISC value will be for the complete image, but it will contain no debug data from the imported first build - that exists only in the first image's build products. The auto-code (defines, struct, pragma write, etc.) should be used from both builds to create the host API code.



# 10

## Optimization Limitations

This section covers optimization limitations.

### 10.1 Compiler/Optimizer Limitations

The Return Address Register (RAR) cannot be written within a called “C” function. For instance, the following construct is not allowed.

```
MyCFunc()  
{  
    rar = <SomeNumber>.  
}
```

#### 10.1.1 Compiler Inline Assembly Limitations

The limitations for inline assembly are the same as those listed in the assembly limitations section.

### 10.2 Assembly/Optimizer Limitations

There are quite a few optimizer limitations to assembled code, however these limitations are all detected by the optimizer such that the optimizer will detect and report any constructs that prevent optimization. Detected constructs that prevent optimization result in the optimize/link stage being abandoned and such that no invalid code is generated.

#### 10.2.1 Indeterminate Return Value Limitation

The optimizer needs to fully understand all possible paths and this is not possible when the RAR register has an un-initialized or otherwise indeterminate value. For instance, the following constructs causes the optimization to fail because the RAR register value is unknown at the time of the return.

```
ThreadStart:  
    seq return;;
```

The following construct also causes the optimizer to fail for the reason that if the call is not taken then the RAR register is un-initialized.

```
ThreadStart:  
    seq if n == false then call MyFunc, flush;;  
    seq return;;
```

#### 10.2.2 Hard-Coded Return Address Limitation

The optimizer does not support code that hardcodes the return address. Any writes to the return address register using an ALU instruction is not supported. An example of an unsupported construct is found below

```
alu ReturnAddr = b;;
```

Please contact the factory for hints on overcoming this limitation.

#### 10.2.3 Register Storage between Threads Limitation

It is not possible to store global static variables in registers such that their value remains valid between threads. The optimizer assumes that all registers begin each thread with garbage data, and that any final register writes at the end of a thread are garbage.

```
ThreadStart:
```

```

    seq diob = diob + 1;;    // Diob contains the thread
count
    seq end;;

```

In the above case the optimizer does not see the diob register value getting used between the increment and the end of the thread and therefore will eliminate the opcode.

## 10.2.4 Invalid Construct Limitation

If the NXP lists a construct as being invalid then use of the construct will cause the optimizer to fail. For instance, a un-flushed seq followed by an flushed seq results in indeterminate eTPU operation per the NXP documentation.

```

    seq goto MyFunc1, no_flush;;
    seq goto MyFunc2, flush;;

```

Another invalid construct per the NXP documentation is the destination of the first of two sequential un-flushed branches being another change-in-flow instruction. For example, use of the following construct will cause the optimizer to fail because the first opcode in the called function is a change-of-flow.

```

MyFunc1:
    seq return, flush ;;

ThreadStart:
    seq goto MyFunc1, no_flush;;
    seq goto MyFunc2, no_flush;;
    < . . . >

```

## 10.2.5 Hard-Coded Value Limitation

All executable code must be generated using either the assembler or compiler. No opcodes generated by hard-coding a value are allowed. A hard-coded opcode is generated when a value is forced as an opcode, as follows.

```

%hex 3F190FF9.

```

Instead, in all cases an equivalent valid opcode can be generated using assembly as follows.

```

#asm( alu a = a >>R p.)

```

## 10. Optimization Limitations

---

### 10.2.6 Multiply-Divide Unit (MDU) Limitations

The MDU significantly complicates the optimizer/analyzer because the MDU's results are not available until multiple instructions later. When writing code using ETEC there is no issue with multiplies and divides because the compiler generates code that the linker/optimizer can handle. However, when writing code in inline or regular assembly the restriction covered here applies.

Currently, following each MDU operation, the following logic that causes the MDU to spin until the operation is completed as indicated by the MacBusy (MB) flag is required. An example of this is shown below.

```
#asm
    mdu p macs a.
MAC_BUSY_SPIN_LOOP:
    if mb == 1 then goto MAC_BUSY_SPIN_LOOP, flush.
    alu p = mach.
#endasm
```

