Compiler Reference Manual

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1 Introduction

The eTPU Embedded C Compiler System is based upon the ISO/IEC 9899 C standard ("C99") and the ISO/IEC TR 18037 Embedded C extension. ETEC is a highly optimizing C compiler for all versions of the eTPU. ETEC has its own version of the programming model with regards to entry table definition and thread function definition, but also has a Legacy Mode mode for compiling software written using existing programming paradigms. This document covers the details of these programming models, the ETEC Tools Suite itself such as command line options, as well as details on the various outputs of the ETEC Compiler Tools Suite.

2 Supported Targets

The ETEC C compiler toolkit current supports the following targets.

eTPU - select Qorivva MPC55xx parts, select Coldfire MCF52xx parts (compiler/linker option '-target=etpu1')

eTPU2 - select Qorivva MPC56xx parts, select STMicro SPC563Mxx parts (compiler/linker option '-target=etpu2')

eTPU2+ - select Qorivva MPC57xx parts. There is not a separate target option for eTPU2+ - use the eTPU2 target. The eTPU2+ has no instruction set differences versus the eTPU2. The only programming model difference is that a third bit has been added to the missing tooth count field in the tooth program register (TPR). If using the default TPR struct defined in the ETpu_Hw.h header file, this third bit is accessed via the previously unused TPR10 field.

3 References

ISO/IEC 9899:TC2 Programming Languages – C

ISO/IEC TR 18037 Programming Languages – C – Extensions to support embedded processors

Enhanced Time Processing Unit (eTPU) Preliminary Reference Manual (ETPURM/D 5/2004 Rev 1)

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Keywords and Abbreviations

Channel Frame	*The collection of channel variables associated with a single eTPU Function or ETEC eTPU Class.*
Channel Variable	*A variable that is addressed relative to the channel base register. This storage is static and there is one copy per channel to which it is assigned at run-time. Sometimes channel variables are referred to as parameters.*
ETEC	*eTPU Embedded C Compiler*
eTPU	*Enhanced Time Processor Unit (and derivatives)*
eTPU-C	*The C code development system for the eTPU by Byte Craft Limited.*
eTPU Class	*The native ETEC programming model aggregates all threads, Member Functions (methods), channel variables and entry tables associated with a single application into a class-like structure called an eTPU class.*

eTPU Function	*An eTPU-C term that refers to a C function that defines a set of channel variables, an entry table, and the threads that make up the vectors for that entry table.* *With regards to ETEC, it refers to entry tables, channel variables and threads that are all associated, an ETEC "class".*
eTPU Thread	*An ETEC term. A C function that can be used as an entry vector, but cannot be called from any other C code.*
SCM	*Shared Code Memory. The location of the eTPU code and entry tables. Not readable from the eTPU.*
SDM	*Shared Data Memory. Multi-ported data memory accessible from the host CPU and the eTPU. Historically this memory has been referred to as parameter RAM.*

5

eTPU Programming Model

This section discusses the two major portions of the eTPU hardware programming model – direct access to the eTPU hardware, and the syntax for defining entry tables. Unlike a more conventional microprocessor, the eTPU does not typically process in any kind of continuous manner. Rather, it behaves more like a set of interrupt handlers reacting to events. Entry tables map events to the code / threads that need to process the event. In between such activations the eTPU microengine is completely idle.

ETEC uses a stack-based approach for local variables and function calls. The user must allocate stack space in SDM. This portion of the programming model is discussed in more detail in the section 4.7.

5.1 Legacy Mode

The ETEC Compiler toolset supports 'Legacy Mode' style programming to maintain compatibility with existing code built using other toolsets. It is possible to mix and match Legacy Mode and 'ETEC Mode' code such that (say) one eTPU Function is built in ETEC mode and another eTPU function is built using Legacy Mode. It is (generally) easy/trivial to convert code from Legacy Mode to Enhanced ETEC Mode.

In Legacy Mode, entry tables are encoded via if-else blocks within functions designated as eTPU Functions. eTPU Functions are designated with a #pragma (different formats shown) that can include table type & function number information:

```
#pragma ETPU_function <func_name>;             // implies standard
```

```
#pragma ETPU_function <func_name> @ <func_num>; // implies standard
#pragma ETPU_function <func_name>, [alternate | standard];
#pragma ETPU_function <func_name>, [alternate | standard] @ <func_num>;
```

The special if-else block resides at the top scope level of the function, with each if expression defining the entry conditions for the ensuing thread. Each compound statement following an if/else represents an eTPU thread. [TBD note: statement following if/else must be a compound statement { } at the current time for proper compilation.] Below, a skeleton of an eTPU Function is shown as an example.

```
#pragma ETPU_function TEST, standard;
// A, B, and C are channel variables
void TEST(int A, int B, int C)
{
     // D is allocated as a channel variable
     static int D;
     int E; // local variable
     if      ((hsr==1) && (pin==0) && (flag0==0))
     {
           int F; // local variable
           // thread 1
     }
     else if (hsr==1)
     {
           // thread 2
     }
     else if (hsr==2)
     {
           // thread 3
     }
     else if (lsr==1)
     {
           // thread 4
     }
     else if ((lsr==0) && (m1==0) && (m2==1))
     {
           // thread 5
     }
     else if ((lsr==0) && (m1==1) && (pin==0))
     {
           // thread 6
     }
     else if ((lsr==0) && (m1==1) && (m2==0) && (pin==1))
     {
           // thread 7
```

```
        }
        else
        {
                // default "catch-all" thread
        }
    }
```

There are up to 7 different inputs into the entry table, although all seven are never meaningful at the same time. The seven entry conditions are:

```
hsr             // host service request – valid value 1-7

channel.LSR     // link service request – 0 or 1;
                // 'lsr' is equivalent to channel.LSR

m1              // match A or transition B – 0 or 1

m2              // match B or transition A – 0 or 1

channel.PIN     // pin value (host setting determines whether
                // it is the input or output pin) – 0 or 1;
                // 'pin' is equivalent to channel.PIN

channel.FLAG0   // channel flag0 – 0 or 1; 'flag0'
                // is equivalent to channel.FLAG0

channel.FLAG1   // channel flag1 – only used in entry tables
                // of alternate type – 0 or 1; 'flag1'
                // is equivalent to channel.FLAG1
```

Besides one exception, tests of these conditions can be logically ANDed and ORed together to determine the conditions for entry into a given thread. Host service request (hsr) conditions can never be ANDed together.

When defining an entry table of alternate type, specifying just one hsr condition from a grouped set is sufficient to cover that group's entries. For example, if (hsr == 1) { … } is equivalent to if ((hsr == 1) || (hsr == 4) || (hsr == 5)) { … }. The latter format is recommended as it is clearer to read & understand.

Within an entry condition specification, the operators ||, &&, !, ==, and != are allowed. The != and ! operators are not allowed for use with the hsr condition, only the other Boolean conditions. The Boolean conditions may also be specified just by themselves (not hsr), e.g. if (m1) { … } which is equivalent to if (m1 == 1) { … }.

The conditions in successive if expressions can overlap; the latter if only covers any remaining open entry table slots for which its conditions apply. If no open slots remain a compilation error is reported. Here's an example of a standard entry table definition:

```
If (hsr == 1)
{
     …
}
Else if  (m1 && m2)
{
     … // covers entry slots 10, 11, 20, 21, 22, 23
}
Else if (m1)
{
     …
// covers entry slots 16, 17, 18, 19, 30, 31
// (but not 10-11, 20-23 since they were already taken)
}
…
```

The if-else array can end in a dangling else that covers any remaining entry slots in the table. A dangling else is required if all of the 'if' expressions do not fully cover a table. Typically the dangling else executes error code.

In each thread defined by the if-else array, the default is for the Match Enable (ME) entry to be set true, matches enabled. The Match Enable can be set explicitly, or disabled, by making one of the below intrinsic function calls or macro synonyms somewhere in the thread (no code is generated by the intrinsic, only the entry ME bit is affected).

```
match_enable();
match_disable();
// synonyms
enable_match();
disable_match();
EnableMatchesInThread();
DisableMatchesInThread();
```

For more information on entry tables and entry conditions reference eTPU documentation.

5.1.1 Legacy Mode Issues

The original eTPU compiler had been available for about 5 years when we noticed that numerous customers experienced repeated instances of common bugs. These bugs were a result of various issues with the Legacy Mode programming model enumerated below. ASH WARE decided to address these issues by developing a new coding mode which we named Enhanced ETEC Mode which would address many of the common issues through the use of an enhanced coding pattern that matches the unique nature of the eTPU. The following drawbacks were addressed.

- It was difficult to share code that accessed Channel Variables in different threads. This lead to the use of unstructured 'GOTOs' . ETEC Mode supports this using Member Functions.

- It was difficult to group functions that could all share Channel Variables, Member Functions, and Threads. ETEC Mode supports this by allowing multiple entry tables in the same eTPU Class. Threads can be referenced by just one (or multiple) Entry Tables.

- Legacy Mode hides critical aspects of the Entry Table making it challenging to properly design the entry table code. The authors of this manual have seen numerous instances of buggy customer code due to major issue. ETEC Mode fully exposes the Entry Table, thereby forcing the user to consider the Entry Table in its entirety and eliminating this common source of buggy code.

- Legacy Mode Entry Table code does not always operate the way it reads. For instance, the order of execution of thread described in the if/else array is defined by the hardware, not by the if else array. It is common for Entry Table code to read one way, but operate a different way. ETEC Mode Entry Tables execute exactly the way they are written.

- Legacy Mode does not operate the way it reads. A common coding error is to attempt to write code before or after the Entry Table defining if/else array. This is not an issue in ETEC Mode because there is no entry table.

- Legacy Mode Entry Table if/else array only supports a small subset of the 'c' language because it must be dedicated solely to the entry table which is not intuitive.This is not an issue in ETEC Mode because there is no entry table.

- Legacy Mode Channel Variables appear to be static and are actually dynamic and it is in no way intuitive that there is a single copy of each Channel Variable for each channel. The way Channel Variables are declared and used in ETEC mode makes it intuitive that each channel gets its own static copy of its Channel Variables.

- Legacy Mode Channel Variables can also be declared using the 'static' keyword within the scope of the eTPU function. In 'C' there is normally one copy of these variables whereas in the eTPU each eTPU channel gets its own copy making these variables very confusing and non-intuitive. ETEC Mode handles Channel Variables in an intuitive way that is obvious that Channel Variables are static and each channel gets its own copy.
- Legacy Mode Channel Variables are all exposed to the host CPU, whereas there are really two categories, those that are shared between the Host CPU and the eTPU and those that are private to the eTPU. ETEC Mode supports this important differentiation through the use of the 'private' and 'public' keywords.

5.2 Enhanced ETEC Mode (eTPU Class)

The Enhanced ETEC Mode was developed to address numerous shortcoming of the earlier Legacy Mode as described in the Legacy Mode Issues section.

The ETEC programming model for the eTPU uses extensions to the C language to more cleanly match the eTPU hardware. A class-like syntax connects all the pieces that apply to a single eTPU channel (or group of channels that must work in concert and share a Channel Variables.) This class-like syntax, referred to as an “eTPU class”, is used to aggregate the data and code that is used to perform a single eTPU function/application.

Although it is somewhat similar in syntax to a C++ class, it is actually quite simplified in that there are no concepts like overloading or derivation Rather it acts as a way to aggregate all the necessary pieces of an eTPU application (typically maps to one channel, but can map to multiple channels) into a clean package. An eTPU Class consists of the following.

- Threads which are sections of code that executed in response to an HSR, LSR, Match or Transition event, detailed in the
- The Entry Table (sometimes referred to as the Event Vector table) which maps events and combinatorial's the event-handling threads.
- Member Functions (methods) that can be called by threads and other member functions and can access channel variables.
- The data which is called the “channel frame”, or Channel Variables.

These are covered in more detail in subsequent sections

- In the eTPU programming model, there is a static copy of the channel frame for each channel, or set of channels, to which the eTPU class is assigned. The assignment itself is done via a combination of the channel function select register (CFSR) and allocating room for the channel frame in SDM (SPRAM) and properly setting the channel parameter base address (CPBA).

The last main piece of an eTPU class is the entry table definition. A class may be associated with one or more eTPU entry tables, each of which has a unique eTPU function number. These entry tables are defined like initialized arrays and the user must explicitly specify an eTPU thread for each of the 32 different entry conditions allowed per table. As part of the entry table definition, table qualifiers such as type (standard or alternate), pin direction, and CFSR (function number) value are specified.

The ETEC compiler supports an alternative syntax for thread declarations. The "_eTPU_thread" keyword can be used interchangeably with "void __attribute__ ((interrupt_handler))", which is a GNU-based syntax.

5.2.1 eTPU Class Example

The example below shows the overall eTPU class syntax. Subsequent sections of this manual describe the following in more detail.

```
// Standard Compiler-supplied header
#include <ETpu_Std.h>

// Exclude Init and Error threads from WCTL calculations
#pragma exclude_wctl MyClass::Init
#pragma exclude_wctl _Error_handler_unexpected_thread

_eTPU_class MyClass
{
   // Channel Variables
   int24 _myChanVar;

   // Thread Declarations
   _eTPU_thread Init(_eTPU_matches_disabled);
   _eTPU_thread HandleMatchA(_eTPU_matches_enabled);

   // Member Functions (methods)
   int24 CalculateOutput(int24 myPassedVar);

   // Entry Table declaration(s)
   _eTPU_entry_table MyClass;
};

_eTPU_thread MyClass::Init(_eTPU_matches_disabled)
{
   // ...
   _myChanVar = tcr1;
   // ...
}

_eTPU_thread MyClass::HandleMatchA(_eTPU_matches_enabled)
{
   // ...
   _myChanVar = CalculateOutput(erta);
   // ...
}

int24 MyClass::CalculateOutput(int24 myPassedVar)
```

```
{
   // Class Member Function can directly access channel variables
   return _myChanVar + myPassedVar;
}

DEFINE_ENTRY_TABLE(MyClass, MyClass, standard, outputpin, autocfsr)
{
   // Host Service Request (HSR) 7
   // is used for initialization
   //          HSR LSR M1 M2 PIN F0 F1 vector
   ETPU_VECTOR1(7,  x,  x, x, x,  x, x, Init),

   // Only valid combination when toggling the output pin
   // using Action Unit A is MRL-A is set and MRL-B is clear
   //          HSR LSR M1 M2 PIN F0 F1 vector
   ETPU_VECTOR1(0,  0,  1, 0, 0,  0, x, HandleMatchA),
   ETPU_VECTOR1(0,  0,  1, 0, 1,  0, x, HandleMatchA),

   // Host Service Requests (HSR) 1 through 5 are not used.
   // Therefore, these HSR's set get steered to the error handler.
   //          HSR LSR M1 M2 PIN F0 F1 vector
   ETPU_VECTOR1(1,  x,  x, x, 0,  0, x, _Error_handler_unexpected_thread),
   ETPU_VECTOR1(1,  x,  x, x, 0,  1, x, _Error_handler_unexpected_thread),
   ETPU_VECTOR1(1,  x,  x, x, 1,  0, x, _Error_handler_unexpected_thread),
   ETPU_VECTOR1(1,  x,  x, x, 1,  1, x, _Error_handler_unexpected_thread),
   ETPU_VECTOR1(2,  x,  x, x, x,  x, x, _Error_handler_unexpected_thread),
   ETPU_VECTOR1(3,  x,  x, x, x,  x, x, _Error_handler_unexpected_thread),
   ETPU_VECTOR1(4,  x,  x, x, x,  x, x, _Error_handler_unexpected_thread),
   ETPU_VECTOR1(5,  x,  x, x, x,  x, x, _Error_handler_unexpected_thread),
   ETPU_VECTOR1(6,  x,  x, x, x,  x, x, _Error_handler_unexpected_thread),

   // Links are not used, should never get a link
   // Therefore, threads with LSR set get steered to the error handler.
   //          HSR LSR M1 M2 PIN F0 F1 vector
   ETPU_VECTOR1(0,  1,  1, 1, x,  0, x, _Error_handler_unexpected_thread),
   ETPU_VECTOR1(0,  1,  1, 1, x,  1, x, _Error_handler_unexpected_thread),
   ETPU_VECTOR1(0,  1,  0, 0, 0,  0, x, _Error_handler_unexpected_thread),
   ETPU_VECTOR1(0,  1,  0, 0, 0,  1, x, _Error_handler_unexpected_thread),
   ETPU_VECTOR1(0,  1,  0, 0, 1,  0, x, _Error_handler_unexpected_thread),
   ETPU_VECTOR1(0,  1,  0, 0, 1,  1, x, _Error_handler_unexpected_thread),
   ETPU_VECTOR1(0,  1,  0, 1, x,  0, x, _Error_handler_unexpected_thread),
   ETPU_VECTOR1(0,  1,  0, 1, x,  1, x, _Error_handler_unexpected_thread),
   ETPU_VECTOR1(0,  1,  1, 0, x,  0, x, _Error_handler_unexpected_thread),
   ETPU_VECTOR1(0,  1,  1, 0, x,  1, x, _Error_handler_unexpected_thread),

   // Although Flag0 is not used,
   // it is set to zero in init.
   // Therefore, threads that respond
   // when Flag0 is set are invalid
   // and get steered to the error handler.
   ETPU_VECTOR1(0,  0,  1, 0, 0,  1, x, _Error_handler_unexpected_thread),
   ETPU_VECTOR1(0,  0,  1, 0, 1,  1, x, _Error_handler_unexpected_thread),

   // Action Unit B is not used.
   // Therefore, MRL-B should never get set.
   // Threads with M2 set get steered to the error handler.
   //         HSR   LSR M1 M2 PIN F0 F1 vector
   //         HSR LSR M1 M2 PIN F0 F1 vector
   ETPU_VECTOR1(0,  0,  0, 1, 0,  0, x, _Error_handler_unexpected_thread),
   ETPU_VECTOR1(0,  0,  0, 1, 0,  1, x, _Error_handler_unexpected_thread),
   ETPU_VECTOR1(0,  0,  0, 1, 1,  0, x, _Error_handler_unexpected_thread),
   ETPU_VECTOR1(0,  0,  0, 1, 1,  1, x, _Error_handler_unexpected_thread),
   ETPU_VECTOR1(0,  0,  1, 1, 0,  0, x, _Error_handler_unexpected_thread),
   ETPU_VECTOR1(0,  0,  1, 1, 0,  1, x, _Error_handler_unexpected_thread),
   ETPU_VECTOR1(0,  0,  1, 1, 1,  0, x, _Error_handler_unexpected_thread),
   ETPU_VECTOR1(0,  0,  1, 1, 1,  1, x, _Error_handler_unexpected_thread),
};
```

5.2.2 Threads

The most critical elements of the eTPU class are the threads. A thread is a section of code that quickly responds to event(s). When a thread ceases to execute it 'ends'. The scheduler then queues up another thread for execution by the execution unit. However, if none of the 32 channels in the engine are requesting service, then the execution unit can actually go idle such that nothing at all is executing. While the execution is 'Idle' (waiting for a channel to request service) the SDM memory is read as part of a 'safety' mechanism to assure that there are no memory errors.

Note that threads are by definition of type 'void' since when a thread ends no data is returned.

```
_eTPU_class MyClass
{
   // <... SNIP ...>
   _eTPU_thread HandleMatchA(_eTPU_matches_enabled);
   // <... SNIP ...>
};

_eTPU_thread MyClass::Init(_eTPU_matches_disabled)
{
   // <... SNIP ...>
   _myChanVar = tcr1;
   // <... SNIP ...>
}
```

5.2.2.1 Enabling/Disabling Matches in the Thread

While a thread executes matches for the channel executing the thread can either be enabled to disabled. Note that this applies to just to the single channel executing the thread. This is controlled by the first argument in the thread declaration as shown below. The setting is called the Match Enable (ME) Bit which is actually encoded into the Entry Table. The keywords that support this are "_eTPU_matches_disabled" and "_eTPU_matches_enabled". It is generally recommended that users write their functions/ threads in such a way that matches can be enabled during thread processing. If possible, only initialization & shutdown threads should have matches disabled.

```
_eTPU_thread HandleMatch(_eTPU_matches_enabled);
```

5.2.2.2 Controlling the Preload Parameter Bit (PP)

Immediately prior to execution of a thread, there is a Time Slot Transition (TST) in which two or three Channel Variables are pre-loaded into the eTPU's execution unity thereby improving performance many cases. There is some configurability in which variables are preloaded which is controlled by the Preload Parameter Bit (PP). It is generally preferable to allow the toolset to control this setting as it is chosen as part of an execution speed and code size optimization strategy. However, this can be overridden using an optional (second) argument in the thread declaration as shown below. Note that supported keywords are "_eTPU_preload_low" and "_eTPU_preload_high". Note that this option is (correctly) seldom used.

```
_eTPU_thread HandleMatch(_eTPU_matches_enabled, _eTPU_preload_high);
```

5.2.3 Entry Tables

The last main piece of an eTPU class is the entry table definition. A class may be associated with one or more eTPU entry tables, each of which has a unique eTPU function number. These entry tables are defined like initialized arrays and the user must explicitly specify an eTPU thread for each of the 32 different entry conditions allowed per table. As part of the entry table definition, table qualifiers such as type (standard or alternate), pin direction, and CFSR (function number) value are specified.

The entry table definition takes the form of an array initializer, with a total of 32 entries, one for each possible unique entry. The entry table is qualified by whether it is alternate or standard, whether it is based upon an input or output pin value, and what channel function select number it should be assigned. The input/output setting generates a #define in the auto header for use during host initialization of the eTPU; note that some microcontrollers only support an input pin setting. It does not actually affect eTPU code generation. The entry table will be given the specified function number, unless during link a conflict is found in which case linking fails. If no function number is specified (autocfsr), the linking process automatically assigns a function number. Each entry vector is specified by its entry conditions, and the thread activated by those conditions. Vectors may be specified in any order as long as the complete set of 32 is defined. To simplify the entry table definition, several macros have been defined. The first begins the table definition:

```
#define DEFINE_ENTRY_TABLE(className, tableName, tableType, pinDirection, cfsrValue)
```

The className and tableName must match the names used in the class declaration. The tableType parameter must be **standard** or **alternate**. The pinDirection argument can be either **inputpin** or **outputpin**. Finally, the cfsrValue can be either a number from [0-31], or it can be **autocfsr**, in which case the linker assigns the entry table a CFSR value.

Then, three different macros are used to specify each entry vector. Three are required since depending upon entry table type, up to 3 HSR values can contribute to the entry.

```
#define ETPU_VECTOR1(hsr1, lsr, m1, m2, pin, flag0, flag1, threadName)
#define ETPU_VECTOR2(hsr1, hsr2, lsr, m1, m2, pin, flag0, flag1, threadName)
#define ETPU_VECTOR3(hsr1, hsr2, hsr3, lsr, m1, m2, pin, flag0, flag1, threadName)
```

Below is an example of the definition of a standard entry table with a user-specified CFSR value.

```
DEFINE_ENTRY_TABLE(ClassName, EntryTableName, standard, inputpin, 3)
{
       //           HSR LSR M1 M2 PIN F0 F1 vector
       ETPU_VECTOR1(1,  x,  x, x, 0,  0, x, Initialize),
       ETPU_VECTOR1(1,  x,  x, x, 0,  1, x, Initialize),
       ETPU_VECTOR1(1,  x,  x, x, 1,  0, x, Initialize),
       ETPU_VECTOR1(1,  x,  x, x, 1,  1, x, Initialize),
       ETPU_VECTOR1(2,  x,  x, x, x,  x, x, Global_Error_Thread),
       ETPU_VECTOR1(3,  x,  x, x, x,  x, x, Global_Error_Thread),
       ETPU_VECTOR1(4,  x,  x, x, x,  x, x, Global_Error_Thread),
       ETPU_VECTOR1(5,  x,  x, x, x,  x, x, Global_Error_Thread),
       ETPU_VECTOR1(6,  x,  x, x, x,  x, x, Global_Error_Thread),
       ETPU_VECTOR1(7,  x,  x, x, x,  x, x, Global_Error_Thread),
       ETPU_VECTOR1(0,  1,  1, 1, x,  0, x, HandleMatch),
       ETPU_VECTOR1(0,  1,  1, 1, x,  1, x, HandleMatch),
       ETPU_VECTOR1(0,  0,  0, 1, 0,  0, x, Global_Error_Thread),
       ETPU_VECTOR1(0,  0,  0, 1, 0,  1, x, Global_Error_Thread),
       ETPU_VECTOR1(0,  0,  0, 1, 1,  0, x, Global_Error_Thread),
       ETPU_VECTOR1(0,  0,  0, 1, 1,  1, x, Global_Error_Thread),
       ETPU_VECTOR1(0,  0,  1, 0, 0,  0, x, HandleMatch),
       ETPU_VECTOR1(0,  0,  1, 0, 0,  1, x, HandleMatch),
       ETPU_VECTOR1(0,  0,  1, 0, 1,  0, x, HandleMatch),
       ETPU_VECTOR1(0,  0,  1, 0, 1,  1, x, HandleMatch),
       ETPU_VECTOR1(0,  0,  1, 1, 0,  0, x, HandleMatch),
       ETPU_VECTOR1(0,  0,  1, 1, 0,  1, x, HandleMatch),
       ETPU_VECTOR1(0,  0,  1, 1, 1,  0, x, HandleMatch),
       ETPU_VECTOR1(0,  0,  1, 1, 1,  1, x, HandleMatch),
       ETPU_VECTOR1(0,  1,  0, 0, 0,  0, x, Global_Error_Thread),
       ETPU_VECTOR1(0,  1,  0, 0, 0,  1, x, Global_Error_Thread),
       ETPU_VECTOR1(0,  1,  0, 0, 1,  0, x, Global_Error_Thread),
       ETPU_VECTOR1(0,  1,  0, 0, 1,  1, x, Global_Error_Thread),
       ETPU_VECTOR1(0,  1,  0, 1, x,  0, x, Global_Error_Thread),
       ETPU_VECTOR1(0,  1,  0, 1, x,  1, x, Global_Error_Thread),
       ETPU_VECTOR1(0,  1,  1, 0, x,  0, x, HandleMatch),
       ETPU_VECTOR1(0,  1,  1, 0, x,  1, x, HandleMatch),
};
```

An example of an alternate entry table might look like:

```
DEFINE_ENTRY_TABLE(UART, UART, alternate, outputpin, autocfsr)
{
        //          HSR    LSR M1 M2 PIN F0 F1 vector
        ETPU_VECTOR2(2,3,   x,  x, x, 0,  0, x, Global_Error_Thread),
        ETPU_VECTOR2(2,3,   x,  x, x, 0,  1, x, Global_Error_Thread),
        ETPU_VECTOR2(2,3,   x,  x, x, 1,  0, x, Global_Error_Thread),
        ETPU_VECTOR2(2,3,   x,  x, x, 1,  1, x, Global_Error_Thread),
        ETPU_VECTOR3(1,4,5, x,  x, x, x,  x, x, TX_INIT),
        ETPU_VECTOR2(6,7,   x,  x, x, x,  x, x, RX_INIT),
        ETPU_VECTOR1(0,     1,  0, 0, 0,  x, x, Global_Error_Thread),
        ETPU_VECTOR1(0,     1,  0, 0, 1,  x, x, Global_Error_Thread),
        ETPU_VECTOR1(0,     x,  1, 0, 0,  0, 0, Test_New_Data_TX),
        ETPU_VECTOR1(0,     x,  1, 0, 0,  1, 0, Send_Serial_Data_TX),
        ETPU_VECTOR1(0,     x,  1, 0, 0,  0, 1, Receive_Serial_Data_RX),
        ETPU_VECTOR1(0,     x,  1, 0, 0,  1, 1, Receive_Serial_Data_RX),
        ETPU_VECTOR1(0,     x,  1, 0, 1,  0, 0, Test_New_Data_TX),
        ETPU_VECTOR1(0,     x,  1, 0, 1,  1, 0, Send_Serial_Data_TX),
        ETPU_VECTOR1(0,     x,  1, 0, 1,  0, 1, Receive_Serial_Data_RX),
        ETPU_VECTOR1(0,     x,  1, 0, 1,  1, 1, Receive_Serial_Data_RX),
        ETPU_VECTOR1(0,     x,  0, 1, 0,  0, 0, Global_Error_Thread),
        ETPU_VECTOR1(0,     x,  0, 1, 0,  1, 0, Global_Error_Thread),
        ETPU_VECTOR1(0,     x,  0, 1, 0,  0, 1, Detect_New_Data_RX),
        ETPU_VECTOR1(0,     x,  0, 1, 0,  1, 1, Detect_New_Data_RX),
        ETPU_VECTOR1(0,     x,  0, 1, 1,  0, 0, Global_Error_Thread),
        ETPU_VECTOR1(0,     x,  0, 1, 1,  1, 0, Global_Error_Thread),
        ETPU_VECTOR1(0,     x,  0, 1, 1,  0, 1, Detect_New_Data_RX),
        ETPU_VECTOR1(0,     x,  0, 1, 1,  1, 1, Detect_New_Data_RX),
        ETPU_VECTOR1(0,     x,  1, 1, 0,  0, 0, Test_New_Data_TX),
        ETPU_VECTOR1(0,     x,  1, 1, 0,  1, 0, Send_Serial_Data_TX),
        ETPU_VECTOR1(0,     x,  1, 1, 0,  0, 1, Detect_New_Data_RX),
        ETPU_VECTOR1(0,     x,  1, 1, 0,  1, 1, Detect_New_Data_RX),
        ETPU_VECTOR1(0,     x,  1, 1, 1,  0, 0, Test_New_Data_TX),
        ETPU_VECTOR1(0,     x,  1, 1, 1,  1, 0, Send_Serial_Data_TX),
        ETPU_VECTOR1(0,     x,  1, 1, 1,  0, 1, Detect_New_Data_RX),
        ETPU_VECTOR1(0,     x,  1, 1, 1,  1, 1, Detect_New_Data_RX),
};
```

The linker would assign a function number to the UART entry table assigned above, and the auto-header output would not contain information for host on setting the entry table to the input or output pin.

Entry tables must contain all 32 of the entry vectors shown above for either a standard or alternate table, however, there is no constraint on the ordering of the entries. They can be re-arranged for ease of reading, etc.

5.2.4 Member Functions (Methods)

Member Functions (methods) are very cool. This is a section of code that can be called from thread and other Member Functions within the same class, thereby addressing the 'two copy' problem of Legacy Mode code. A key aspect of Member Functions (and an important way the differ from regular 'c' functions) is that they can access the channel variables. See below.

```
    _eTPU_class MyClass
```

```
{
   // <... SNIP ...>
   // Member Functions (methods)
   int24 CalculateOutput(int24 myPassedVar);
   // <... SNIP ...>
};

int24 MyClass::CalculateOutput(int24 myPassedVar)
{
   // Class Member Function can directly access channel
variables
   return _myChanVar + myPassedVar;
}
```

A frustration with Member Functions in the Scratchpad or Engine programming model is that they pass parameters either in 'Global Scratchpad' or in the 'Engine' data space. A workaround is to set the programming model for just this code file to the 'Stack' programming model. This has the advantage that the 'Stack' programming model passes the first few parameters in registers which is significantly faster and tighter. Then, to make sure that no stack is actually used, use the following pragma.

```
#pragma verify_memory_size stack 0 bytes
```

The above does not actually force there to be no variables passed on a stack. Instead, it makes this potential problem observable by issuing a compile-time error.

5.2.4.1 Member Function Fragments

Member Functions can also be declared as 'fragments' which have no 'return'. Instead, execution always ends in the fragment. This eliminates much of the call/return structure thereby reducing code and increasing execution speed as shown below in mixed source/assembly view.

```
_eTPU_fragment MyClass::DoSomethingThenEnd(int24 myPassedVar)
{
   link = myPassedVar + 0x3;
080C: 0x000A1471   alu    link = sr+0x3;; FormatA2 [4]
}
0810: 0x0FFFFFFF   seq   end;;          FormatB3 [4]

_eTPU_thread MyClass::Init(_eTPU_matches_disabled)
{
   // ...
   _myChanVar = tcr1;
0814: 0xBFFC7B80   alu    p = tcr1+0x0; FormatB2 [0]
    : 0xBFFC7B80   ram   *((channel int24 *) 0x1) = p_23_0;; FormatB2 [4]
   DoSomethingThenEnd(0x5);
0818: 0xF7F04067   seq  goto addr_0x80C, no_flush;; FormatE1 [4]
081C: 0x00100430   alu    sr = ((u24) 0)+0x5;; FormatA1 [4]
   // ...
}
```

5.2.5 Channel Variables

Class data is called the “channel frame” which consists of one of more Channel Variables. Each channel contains its own variable-sized channel frame. There is a static copy of the channel frame for each channel, or set of channels, to which the eTPU class is assigned. The assignment itself is done via a combination of the channel function select register (CFSR) and allocating room for the channel frame in SDM (SPRAM) and properly setting the channel parameter base address (CPBA).

```
_eTPU_class MyClass
{
   // Channel Variables
   int24 _myChanVar1, _myChanVar2;
   int8 _myiBitChanVar;
   // <... SNIP ...>
```

5.2.5.1 Hiding Channel Variables (Public/Private)

The visibility of eTPU classes Channel Variables can be 'public' (the default) or 'private' visibility setting using the "public" and "private" keywords, much like in C++. Items get their visibility setting based on the nearest visibility keyword declared above them, or are "public" if no visibility keywords are present. The visibility setting only applies to Channel

Variables and whether their interface information is exported into the auto-defines and auto-struct files. Private data is not referenced in the generated auto-defines and/or auto-struct. Below is an example class definition showing this feature.

```
_eTPU_class Test
{
public:
     int r1;
     int r2;

private:
     int op1;
     int op2;

public:
     int r3;
     int r4;

private:
     int op3;
     int8 op4;
     struct S op5;

     // methods

     // threads
     _eTPU_thread Main(_eTPU_matches_enabled);

     // entry tables
     _eTPU_entry_table Test;
};
```

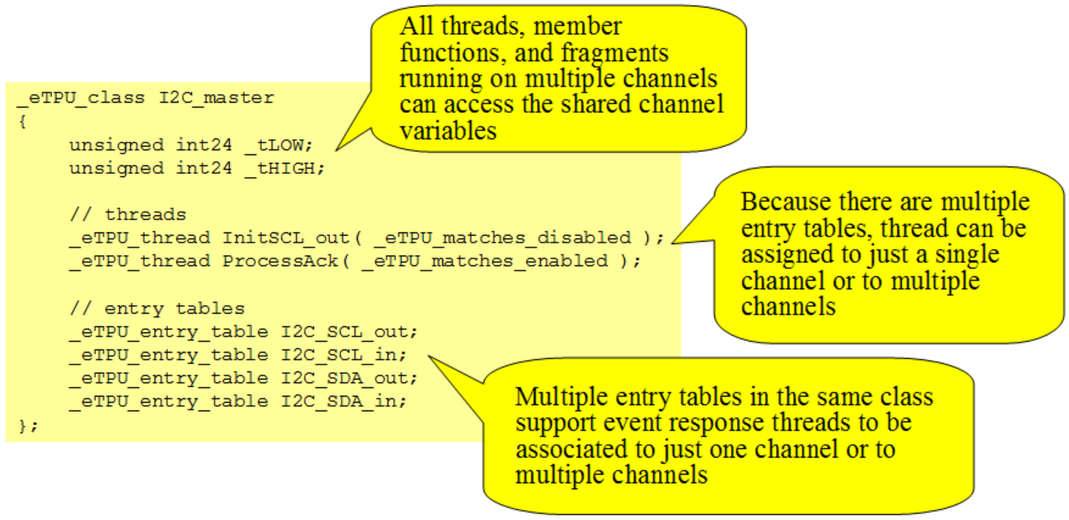
The Channel Variables r1 - r4 are public and their location information will be output in the auto-defines and auto-struct files. The opN variables are private and will not be exposed in the auto-generated interface files.

5.2.6 Channel Groups

Multiple channel groups are really cool! Multiple channel groups can …

- Share channel variables.
- Contain any combination of shared and unshared threads.
- Have separate entry tables.
- The I2C code found below is available for download from the ASH WARE website.

The I2C code found below is available for download from the ASH WARE website



```
_eTPU_class I2C_master
{
    unsigned int24 _tLOW;
    unsigned int24 _tHIGH;

    // threads
    _eTPU_thread InitSCL_out( _eTPU_matches_disabled );
    _eTPU_thread ProcessAck( _eTPU_matches_enabled );

    // entry tables
    _eTPU_entry_table I2C_SCL_out;
    _eTPU_entry_table I2C_SCL_in;
    _eTPU_entry_table I2C_SDA_out;
    _eTPU_entry_table I2C_SDA_in;
};
```

All threads, member functions, and fragments running on multiple channels can access the shared channel variables

Because there are multiple entry tables, thread can be assigned to just a single channel or to multiple channels

Multiple entry tables in the same class support event response threads to be associated to just one channel or to multiple channels

5.2.7 Extension Syntax Details

The ETEC syntax extensions have been added into the C99 grammar as follows:

Several productions have been added to type-specifier:

```
type-specifier:
        …
        etpu-class-specifier
        _eTPU_thread
        _eTPU_entry_table
        // only to be used in thread declaration / definition
        _eTPU_matches_enabled
        // only to be used in thread declaration / definition
        _eTPU_matches_disabled
```

```
          // only to be used in thread declaration / definition
          _eTPU_preload_low
          // only to be used in thread declaration / definition
          _eTPU_preload_high

     etpu-class-specifier:
          // function declarators are
          //allowed in the struct-declaration-list
          _eTPU_class identifier { struct-declaration-list }
```

The following production has been added to declarator:

```
     declarator:
          …
          scope director-declarator

     scope:
          scope-name ::

     scope-name:
          identifier  // eTPU class name
```

The following productions have been added to type-qualifier – they can only apply to the _eTPU_entry_table type:

```
     Type-qualifier:
          …
          _eTPU_standard_ET
          _eTPU_alternate_ET
          _eTPU_inputpin_ET
          _eTPU_outputpin_ET
          _eTPU_cfsr_[0-31]_ET
          _eTPU_cfsr_autocfsr_ET
```

In order to support the public/private feature, two productions have been added to struct_declaration:

```
     struct_declaration
          specifier_qualifier_list struct_declarator_list ';'
          'public' ':'
          'private' ':'
```

5.3 eTPU Types

The C basic types map to the eTPU hardware as follows:

Type	Size	Notes
char, unsigned char	8 bits	int8 is a synonym for char
short, unsigned short	16 bits	int16 is a synonym for short
int, unsigned int	24 bits	int24 is a synonym for int
long int, unsigned long int	32 bits	int32 is a synonym for long int; 32-bit int usage is limited as the eTPU ALU only operates on 24-bits. Essentially only load/store operations are supported. Any use of 32-bit data in an expression that involves arithmetic operations outside assignment (load/ store) result in compilation errors. Conversion via typecast to signed/ unsigned int32 is supported.
long long int, unsigned long long int	32 bits	treated like long types (see comment above)
_Bool	1 bit / 8 bits	_Bool needs to hold 0 or 1. By default, it is packed into 1 bit that is part of an 8-bit unit. Global _Bool variables consume an entire 8-bit unit by themselves so that external linking works correctly. Up to 8 channel frame _Bool variables can packed into one 8-bit unit. Arrays of _Bool are treated as special "bit arrays" and are limited to a length of 24.

Type	Size	Notes
		If the –ansi mode is specified, then all _Bools consume and 8 bits and arrays of _Bools are similar to arrays of chars.
_Complex	Not supported	Not supported
float	Not supported	Not supported
double	Not supported	Not supported

The TR 18037 Embedded C extensions defines additional types. ETEC supports these as follows:

Type	Size	Notes
no TR18037 defined type [use 'fract8']	8 bits, s.7 format	fract8 is a synonym
no TR18037 defined type [use 'unsigned fract8']	8 bits, 0.8 format	unsigned fract8 is a synonym
short _Fract	16 bits, s.15 format	fract16 is a synonym for short _Fract
unsigned short _Fract	16 bits, 0.16 format	unsigned fract16 is a synonym for unsigned short _Fract
_Fract	24 bits, s.23 format	fract24 is a synonym for _Fract
unsigned _Fract	24 bits, 0.24	unsigned fract24 is a synonym for

Type	Size	Notes
	format	unsigned _Fract
long _Fract	32 bits, s.31 format	fract32 is a synonym for long _Fract. Note the eTPU ALU/MDU does not support 32-bit operations so 32-bit fract operations are relegated to load/store.
unsigned long _Fract	32 bits, 0.32 format	unsigned fract32 is a synonym for unsigned long _Fract. Note the eTPU ALU/MDU does not support 32-bit operations so 32-bit fract operations are relegated to load/store.
_Accum	TBD	TBD

5.4 Pointers

Pointers in the eTPU programming model are sized to 24-bits as this is the natural size of the machine (16-bits would provide sufficient range, however). In the default mode, pointers to 8-bit types increment in 1-byte steps, 16-bit types increment in 2-byte steps, and pointers to 24-bit types increment in 4 bytes steps. Some data packing modes cause all pointers to basic types to increment in 4 byte steps (see later sections).

All pointers are always kept in global address space. Thus when the address operator is applied to a channel frame variable the address is computed to be the sum of the channel frame offset and the CPBA register. The same is true with eTPU2 engine-relative address space.

_Bool pointer note. Pointers to type _Bool are allowed, and will increment/decrement like a pointer to an 8-bit. Depending upon _Bool bit packing they may point to any of the 8 bits in a _Bool unit. It is recommended pointers to type _Bool not be used, unless in ANSI mode.

5.5 eTPU Data Packing

Because of the unique memory & addressing architecture of the eTPU, memory allocation of variables and data packing is a much more complex process than in many processor architectures. The sections below provide details on how global variables are allocated, channel frame variables, and lastly the aggregate types: structures/unions and arrays. Note that the array packing option also impacts the behavior of pointer arithmetic; see section 4.3.11 for details.

Most of the packing algorithms are based around the following information:

The natural data sizes of the eTPU memory architecture are 1-byte, 3-byte and 4-byte (limited 4-byte support, however – just load/store).

Single-byte data is best accessed when placed in a modulo 4 address, unless it does not share a 3-byte location with any other data.

3-byte data is best accessed when placed in an address that is modulo 4 plus 1.

Packing multiple non-3-byte (< 3) data into 3-byte locations can result in data coherency issues.

Multiple data packing modes are available in order to help tailor compilation to the application requirements. Note however, that linking object files compiled under different modes will result in link errors in many cases. It is highly recommended that all object files to be linked be compiled with the same data packing settings (the linker has checks for this).

5.5.1 Global Variables

Because global variables can be declared in one translation unit (source file), and referenced externally by other translation units, the global variable packing algorithm must properly account for this in order to have a reasonable linking process. To that end, all global variables are allocated at natural locations for their size. Thus all 1-byte data variables are located at modulo 4 addresses, all 3 byte variables at modulo 4 plus 1 addresses, etc. Note that by default global variables are located starting at address 0 of shared data memory (SDM).

Given these global declarations:

```
char c1, c2, c3, c4;
int32 s32;
```

```
unsigned int16 u16;
int s24;
struct SomeStruct somestruct; // sizeof(SomeStruct) == 8
```

The memory allocation looks like:

SDM Address	*MSByte*	*3 LSBytes*	
0	*c1*	*unused*	*u16*
4	*c2*	*s24*	
8	*c3*	*unused*	
12	*c4*		
16	*s32*		
20	*somestruct*		
24			

Note that the order of declaration does not necessarily match the address order of the variable locations. This is necessary to avoid significant wasted memory. Also note that global variables declared in different translation units may be intermixed in the final linked memory map depending upon sizes and fitting (link) order.

All implicitly located global variables must fit in the directly accessible portion of shared data memory (SDM), which on the eTPU is the first 1KB. It is possible to explicitly locate global variables in any portion of SDM - see Explicitly Locating Global Variables for more information.

5.5.2 Static Variables in Callable C-Functions

Because these types of C functions are not associated with a particular eTPU Function (or eTPU Class), any static variables declared within them cannot be assigned to a channel frame. Thus they are assigned global storage. WARNING: if using a dual eTPU part (e. g. MPC5554) and running code containing such static variables on BOTH eTPUs, there is risk of collisions between the two. This must be taken into consideration when using such a construct; use of semaphore protection may be required depending upon the intended application.

5.5.3 Explicitly Locating Global Variables

Global variables can be explicitly located in any part of shared data memory (SDM) via the #pragma locate_symbol preprocessor directive. This capability should be used carefully and is primarily provided as a way to locate large data items and buffers at the end of SDM. More detailed information can be found in the Explicit Locating section of the manual.

5.5.4 eTPU2 Engine Relative Address Space

Variables can specified for allocation in engine-relative address space through use of the _ENGINE intrinsic address-space type qualifier. Note that automatic variables cannot be so qualified; variables declared within the scope of a function with the _ENGINE qualifier must have a storage class of either static or extern. Such variables are allocated with respect to the user-configured engine base address register.

```
_ENGINE int24 e_duty_cycle;
```

On a dual-eTPU2 microcontroller, each engine references unique copies of e_duty_cycle, assuming the engine-relative base address has been configured properly for each eTPU2. It is generally recommended that the use of engine-relative variables be avoided as they complicate the memory layout. An exception is if the user is also selecting the engine scratchpad programming model.

5.5.5 eTPU Channel Frame Variables

Although channel frames are configured and located at run-time, channel variable allocation is static to the channel frame base and thus the compilation process. The mechanism for declaring channel variables differs between Legacy Mode and Enhanced

ETEC Mode, but in either case there are two packing modes for channel variables. The default mode is called "PACKTIGHT", and its goal is to use the least memory possible in the allocation of the channel frame while still providing reasonable performance. The other mode is called "FASTACCESS", which places variables at their most natural locations for efficient processing, even though it can result in more "holes" of unused memory in a channel frame and thus greater memory usage. In either case, the order of declaration does not necessarily result in monotonically increasing address offsets.

The default PACKTIGHT mode is described in more detail below; FASTACCESS is described in an appendix. In either case the algorithm could change slightly over time, OR the optimizer could re-arrange parameters depending upon level of optimization specified. Should a user want complete control over the location of channel variables they should use the explicit locating mechanism described in section 4.3.8 (TBD).

5.5.6 Channel Frame PACKTIGHT Mode

The PACKTIGHT mode packing algorithm first locates every variable of size 3 bytes or larger. Next variables of size 2 bytes are located, followed by 1-byte variables last.

The set of channel frame variables (likely declared as parameters to an eTPU function in Legacy Mode):

```
int x, y;  // 24-bit vars
char c1, c2, c3, c4, c5, c6;
short a, b, c; // 16-bit vars
struct SomeStruct somestruct; // sizeof(SomeStruct) == 8
```

Would get packed like:

SDM Channel Frame Address Offset	*MSByte*	*3 LSBytes*
0	*c1*	*x*
4	*c2*	*y*
8	*somestruct*	
12		

16	*a*		*b*	
20	*c*		*c3*	*c4*
24	*c5*	*c6*	*unused*	

Note that tight packing can potentially introduce coherency issues, such as at address offsets 16 (a, b) and 20 (c3, c4, c). In general, it is best to avoid 16-bit data in eTPU code, and to avoid 8-bit data ending up in non-optimal locations.

5.5.7 Local/Stack Variables

The ETEC compiler aggressively uses registers for local / temporary variables when possible, but sometimes such variables need to be stored in memory (e.g. when they have the & address operator applied to them). ETEC uses a stack-based approach for local variable overflow. Each stack variable takes up at least one 4-byte data word, and more if the variable has size greater than 4 bytes, allowing for efficient access to such variables.

5.5.8 Structures & Unions

Like channel frames, structures can be packed in either a "PACKTIGHT" mode or a "FASTACCESS" mode. For structures, one additional mode exists – "LEGACY". An additional variable is ANSI mode, which forces the compiler to allocate members in monotonically increasing offset order, even though the result can be significant wasted memory.

Unions do not need to be packed, per se, as union members overlay each other. However, by ANSI/ISO standard every union member is expected to be placed at an offset of 0 from the union base… but that is not very practical on the eTPU with its unusual addressing constraints. Take this union for example:

```
union ExampleUnion
{
    int24 s24;
    int8 array[4];
    int16 s16;
    int8 s8;
};
```

For efficient access, the byte offsets for the union members are best s24 -> 1, array -> 0, s16 ->2, s8 -> 0. When ANSI mode is enabled, such a union would generate a warning; the compiler will not (at this time) attempt to generate ANSI-compatible unions.

The data packing of C structures faces some of same issues discussed in channel frame packing, with an additional twist. Per ANSI/ISO standard, struct member offsets are expected to be in monotonically increasing order, however, on the eTPU this can result in impractical data packing and significant memory waste. Once again there are essentially two data packing flavors: “PACKTIGHT” attempts to minimize the amount of wasted memory, while structures are laid out in “FASTACCESS” mode to promote efficient access, potentially at the cost of extra memory usage. The third mode, “LEGACY”, is only for handling certain cases where existing code is highly dependent upon the packing done by legacy tools (e.g. a mix of C code and inline assembly). “LEGACY” packing is very similar to “PACKTIGHT” except that members such is 8-bit variables will pack in holes only within the last 4 bytes; they will not get packed back at the very first hole available in the structure.

The default mode packing algorithm, PACKTIGHT, is detailed below. The algorithm may change over time so it is recommended to always use the auto define data for referencing structures from the host side. If complete control of data packing is required, the explicit member locating constructs should be used. Also note that the ANSI mode affects structure packing by forcing offsets to monotonically increasing.

5.5.9 Structure PACKTIGHT Mode

This is the default mode of the compiler, and uses the same algorithm as the channel frame PACKTIGHT pack mode. The one difference occurs on small structs where the component member’s size totals 3 bytes or less. In this case the struct is packed to fit in the same slot that basic typed variables of the same size would occupy. Some examples:

```
struct ByteBitfield
{
     int8 a:2;
     int8 b:3;
     int8 c:3;
}; // sizeof() == 1, gets packed like a char in channel
frame, array, etc.

struct TwoByteStruct
{
     char x; // offset 0
```

```
    char y; // offset 1
}; // sizeof() == 2, gets packed like an int16

struct ThreeByteStruct
{
    int16 twobytes; // offset 1
    int8 onebyte; // offset 0
}; // sizeof() == 3, gets packed like an int24
```

The set of struct members:

```
int x, y;  // 24-bit vars
char c1, c2, c3, c4, c5, c6;
short a, b, c; // 16-bit vars
struct SomeStruct somestruct; // sizeof(SomeStruct) == 8
```

Would get packed like:

SDM Channel Frame Address Offset	*MSByte*	*3 LSBytes*		
0	*c1*	*x*		
4	*c2*	*y*		
8	*somestruct*			
12				
16	*a*		*b*	
20	*c*		*c3*	*c4*
24	*c5*	*c6*	*unused*	

The sizeof() this struct would be 28, including the two padding bytes at the end.

5.5.10 Structure Bit Fields

Bitfields can be made out of int8, int16 or int24 types. Bitfields are allocated starting with least significant bit of the storage unit, and are never split across storage units by ETEC.

```
struct BitFieldExample
{
     int24 x : 10; // bit offset == 14
     int24 y : 10; // bit offset == 4
     int24 z : 10; // bit offset == 46
}; // sizeof() == 8
```

Structures (and thus bitfields) can also be mapped onto a register using the TR18037 named register concept, e.g.

```
struct tpr_struct {
     unsigned int16 TICKS   : 10;
     unsigned int16 TPR10   : 1;
     unsigned int16 HOLD    : 1;
     unsigned int16 IPH     : 1;
     unsigned int16 MISSCNT : 2;
     unsigned int16 LAST    : 1;
} register _TPR tpr_reg;
```

5.5.11 Arrays

The packing of arrays is also tied into how pointer arithmetic is handled in the compilation process. Pointer arithmetic follows the array stride size settings, which are governed by the array packing mode. Once again, the modes are termed PACKTIGHT (default) and FASTACCESS. Because this setting affects pointer arithmetic (e.g. in FASTACCESS mode incrementing a char pointer results in an increment by 4 bytes), care should be taken in using the non-default setting. Additional PACKTIGHT mode specifics are given below; further FASTACCESS information is in the appendix.

Note that FASTACCESS and ANSI modes are incompatible and compilation will error.

5.5.12 Array PACKTIGHT Mode

In array PACKTIGHT mode, the array stride size matches the element size with the exception of 24-bit elements. For element types with a byte size of 3, the array stride size is 4 bytes, thus leaving an unused byte between each element. These unused bytes are open to be allocated, except if ANSI mode is enabled. Once an element is greater than 4 bytes in size, the stride size is rounded up to the next multiple of 4 bytes. Once again, the unused memory between array elements is open for allocation (under default settings).

Some example declarations and the ensuing memory allocations are shown below:

```
char a[6];
int b[3];
struct FiveByteStruct
{
    char f1;
    int f2;
    char f3;
} c[2];
int24 x;
int8 y;
int16 z;
```

The resulting memory allocation map would look like (PACKTIGHT channel frame pack mode):

SDM Channel Frame Address Offset	*MSByte*	*3 LSBytes*		
0	*a[0]*	*a[1]*	*a[2]*	*a[3]*
4	*a[4]*	*a[5]*	*z*	
8	*y*	*b[0]*		
12	*unused*	*b[1]*		
16	*unused*	*b[2]*		
20	*c[0].f1*	*c[0].f2*		

24	*c[0].f3*	*x*
28	*c[1].f1*	*c[1].f2*
32	*c[1].f3*	*unused*

5.5.13 ANSI Mode

ANSI mode (controlled with the –ansi option) has been mentioned several times above. Essentially it forces ANSI/ISO compatibility wherever possible, particularly in data packing (structs are always packed in order, for example). Also, _Bools are packed as 8-bit units rather than as single bits (LSB holds the 0 or 1 value). It is not recommended for use in production eTPU code as it typically increases memory usage and decreases performance.

5.6 eTPU Hardware Access

Most eTPU hardware access involves the channel hardware or portions of the register set. The underlying hardware programming model described here is defined in the ETpu_Hw.h header file that is part of the ETEC distribution.

5.6.1 Channel Hardware Access

The channel hardware is represented by a large structure of bitfields. Each field represents an accessible piece of channel hardware. This structure type has the name chan_struct and as part of the standard programming model a “variable” of this type named “channel” is declared. No actual memory space is allocated. Most fields are write-only, none are readable in the normal sense. Some are test-only, whereas a few are both writeable and testable.

5.6.2 Baseline eTPU Channel Hardware Programming Model

The eTPU chan_struct is defined as:

```
typedef struct {
    CIRC   int : 2 ;  // write-only
    ERWA   int : 1 ;  // write-only
    ERWB   int : 1 ;  // write-only
    FLC    int : 3 ;  // write-only
    IPACA  int : 3 ;  // write-only
    IPACB  int : 3 ;  // write-only
    LSR    int : 1 ;  // writeable, testable, entry condition
    MRLA   int : 1 ;  // writeable, testable
    MRLB   int : 1 ;  // writeable, testable
    MRLE   int : 1 ;  // write-only
    MTD    int : 2 ;  // write-only
    OPACA  int : 3 ;  // write-only
    OPACB  int : 3 ;  // write-only
    PDCM   int : 4 ;  // write-only
    PIN    int : 3 ;  // write-only
    TBSA   int : 4 ;  // write-only
    TBSB   int : 4 ;  // write-only
    TDL    int : 1 ;  // write-only
    SMPR   int : 2 ;  // writeable, testable
                      // [setting to -1 triggers semaphore free]
    FLAG0  int : 1 ;  // writeable (also via FLC), entry condition
    FLAG1  int : 1 ;  // writeable (also via FLC), entry condition
    FM0    int : 1 ;  // test-only
    FM1    int : 1 ;  // test-only
    PSS    int : 1 ;  // test-only
    PSTI   int : 1 ;  // test-only
    PSTO   int : 1 ;  // test-only
    TDLA   int : 1 ;  // test-only
    TDLB   int : 1 ;  // test-only
} chan_struct;
```

See eTPU documentation for the details on each field.

Note that the ETpu_Std.h header file defines many macros that simplify interaction with the channel hardware and make it more user-friendly.

5.6.3 eTPU+ Extensions to the Channel Hardware Programming Model

For the eTPU+, chan_struct has been modified and extended to the following:

```
typedef struct {
    CIRC    int : 3 ;  // write-only
    ERWA    int : 1 ;  // write-only
    ERWB    int : 1 ;  // write-only
    FLC     int : 3 ;  // write-only
    IPACA   int : 3 ;  // write-only
    IPACB   int : 3 ;  // write-only
    LSR     int : 1 ;  // writeable, testable, entry condition
    MRLA    int : 1 ;  // writeable, testable
    MRLB    int : 1 ;  // writeable, testable
    MRLE    int : 1 ;  // write-only
    MTD     int : 2 ;  // write-only
    OPACA   int : 3 ;  // write-only
    OPACB   int : 3 ;  // write-only
    PDCM    int : 4 ;  // write-only
    PIN     int : 3 ;  // write-only
    TBSA    int : 4 ;  // write-only
    TBSB    int : 4 ;  // write-only
    TDL     int : 1 ;  // write-only
    UDCMRWA int : 1 ;  // write-only
    SMPR    int : 2 ;  // writeable, testable
                       // [setting to -1 triggers semaphore free]
    FLAG0   int : 1 ;  // writeable (also via FLC),
                       // testable, entry condition
    FLAG1   int : 1 ;  // writeable (also via FLC),
                       // testable, entry condition
    FM0     int : 1 ;  // test-only
    FM1     int : 1 ;  // test-only
    PSS     int : 1 ;  // test-only
    PSTI    int : 1 ;  // test-only
    PSTO    int : 1 ;  // test-only
    TDLA    int : 1 ;  // writeable, testable
    TDLB    int : 1 ;  // writeable, testable
} chan_struct;
```

The following changes have been made to the eTPU+ chan_struct channel hardware programming model from the baseline:

```
New fields are:

    UDCMRWA   - Controls writing of erta register to the UDCM register.
                Writing a value of 0 to this field triggers
                the write to the UDCM register.

Modified fields are:

    CIRC      - This field has been extended by 1 bit,
                with this new bit treated as inverted.
                The 3-bit CIRC field then has the following meanings:
```

```
Value  ~CIRC[2]  CIRC[1]  CIRC[0]  Meaning
-----  --------  -------  -------  -------
  0       0         0        0     channel interrupt request from
                                   service channel [same as eTPU]
  1       0         0        1     data transfer request from
                                   service channel [same as eTPU]
  2       0         1        0     global exception [same as eTPU]
  3       0         1        1     do nothing; don't request
                                   interrupt [same as eTPU]
  4       1         0        0     channel interrupt request from
                                   current channel
  5       1         0        1     data transfer request from
                                   current channel
  6       1         1        0     channel interrupt & data
                                   transfer request from current
                                   channel
  7       1         1        1     channel interrupt & data
                                   transfer request from service
                                   channel

FLAG0     - Now testable for conditional jumps

FLAG1     - Now testable for conditional jumps

TDLA      - Now writeable (clearable) independent of TDLB

TDLB      - Now writeable (clearable) independent of TDLA
```

5.6.4 eTPU2 Extensions to the Channel Hardware Programming Model

For the eTPU2, chan_struct has been modified and extended to the following:

```
typedef struct {
    CIRC    int : 3 ;  // write-only
    ERWA    int : 1 ;  // write-only
    ERWB    int : 1 ;  // write-only
    FLC     int : 3 ;  // write-only
    IPACA   int : 3 ;  // write-only
    IPACB   int : 3 ;  // write-only
    LSR     int : 1 ;  // writeable, testable, entry condition
    MRLA    int : 1 ;  // writeable, testable
    MRLB    int : 1 ;  // writeable, testable
    MRLE    int : 1 ;  // write-only
    MTD     int : 2 ;  // write-only
    OPACA   int : 3 ;  // write-only
    OPACB   int : 3 ;  // write-only
    PDCM    int : 4 ;  // write-only
    PIN     int : 3 ;  // write-only
    TBSA    int : 4 ;  // write-only
    TBSB    int : 4 ;  // write-only
    TDL     int : 1 ;  // write-only
    UDCMRWA int : 1 ;  // write-only
    SMPR    int : 2 ;  // writeable, testable
                       // [setting to -1 triggers semaphore free]
    FLAG0   int : 1 ;  // writeable (also via FLC),
                       // testable, entry condition
    FLAG1   int : 1 ;  // writeable (also via FLC),
                       // testable, entry condition
    FM0     int : 1 ;  // test-only
    FM1     int : 1 ;  // test-only
    PSS     int : 1 ;  // test-only
    PSTI    int : 1 ;  // test-only
    PSTO    int : 1 ;  // test-only
    TDLA    int : 1 ;  // writeable, testable
    TDLB    int : 1 ;  // writeable, testable
    MRLEA   int : 1 ;  // write-only
    MRLEB   int : 1 ;  // write-only
} chan_struct;
```

The following changes have been made to the eTPU2 chan_struct channel hardware programming model from the eTPU+:

```
New fields are:

    MRLEA     - Now writeable (clearable) independent of MRLEB
               (MRLE still clears both latches)

    MRLEB     - Now writeable (clearable) independent of MRLEA
               (MRLE still clears both latches)
```

In order to allocate variable storage to eTPU2 engine-relative space, the address-space type qualifier _Engine should be used.

5.6.5 Register Access

The eTPU has several special-purpose registers for which direct C-level access is appropriate. In fact all registers can be accessed using the TR18037 named register feature. The following named register keywords have been implemented in ETEC:

```
_A
_B
_C
_D
_CHAN
```

```
_DIOB
_ERTA
_ERTB
_LINK
_MACH
_MACL
_P
_RAR
_SR
_TCR1
_TCR2
_TPR
_TRR
_CHANBASE
_P_31_24
_P_23_16
_P_15_8
_P_7_0
_P_31_16
_P_15_0
_P_31_0
_CC
```

These names are qualifiers to the ‘register’ storage class keyword. Typedefs have been defined for the entire register set, using the names register_<name> in order to be compatible with many existing applications (see etpu_hw.h). They are as follows:

```
typedef register _A          register_ac;
typedef register _B          register_b;
typedef register _C          register_c;
typedef register _D          register_d;
typedef register _CHAN       register_chan;
typedef register _DIOB       register_diob;
typedef register _ERTA       register_erta;
typedef register _ERTB       register_ertb;
typedef register _LINK       register_link;
typedef register _MACH       register_mach;
typedef register _MACL       register_macl;
typedef register _P          register_p;
typedef register _RAR        register_rar;
typedef register _SR         register_sr;
typedef register _TCR1       register_tcr1;
typedef register _TCR2       register_tcr2;
typedef register _TPR        register_tpr;
typedef register _TRR        register_trr;
typedef register _CHANBASE   register_chan_base;
typedef register _P_31_24    register_p31_24;
typedef register _P_23_16    register_p23_16;
typedef register _P_15_8     register_p15_8;
typedef register _P_7_0      register_p7_0;
typedef register _P_31_16    register_p31_16;
typedef register _P_15_0     register_p15_0;
typedef register _P_31_0     register_p31_0;
typedef register _CC         register_cc;
```

register_cc (register _CC) does not map to an actual physical register that can be read/ written by the eTPU. The register_cc type provides direct access to the ALU and MDU condition codes. This is discussed further in the next section.

The register_chan_base (register _CHANBASE) type provides a way to specify a channel relative pointer.

For the most part, the variables of the general purpose register types should not need to be declared (e.g. a, p, diob, b, c, d, sr, macl, mach). In some cases variables of these registers act as aliases only – they do not allocate them for the sole use of the variable (e.g. p). However, registers a, b, c, d, diob and sr can be allocated directly by the user, locking out the compiler from using them (except stack access can override b & diob). This capability should be used very carefully as it can prevent the compiler from generating code resulting in compilation errors.

An important difference between named register variables declared in a function scope, and local variables which the compiler assigns to registers, occurs on function calls. Named register variables are not saved/restored to prevent overwriting by the called function; instead they are treated as if they have a global scope. True local variables, on the other hand, are saved/restored if necessary when function calls are made.

The special purpose registers need to frequently be directly accessed, and are therefore are declared in the ETpu_Hw.h header file as follows:

```
register_chan      chan ;      // 5 bits
register_erta      erta ;      // 24 bits
register_erta      ertA ;      // 24 bits
register_ertb      ertb ;      // 24 bits
register_ertb      ertB ;      // 24 bits
register_tcr1      tcr1 ;      // 24 bits
register_tcr2      tcr2 ;      // 24 bits
register_tpr       tpr  ;      // 16 bits
register_trr       trr  ;      // 24 bits
```

```
        register_link       link ;       // 8 bits
```

5.6.6 ALU Condition Code Access

Although best to avoid as a general coding practice, the ALU and MDU condition codes can be accessed (tested) directly via _CC (register_cc). The comment in ETpu_Hw.h best describes this feature:

```
// register_cc type is syntactically accessed like a struct (bitfield)
// of the following declaration:
// typedef struct {
//      unsigned int V : 1; // ALU overflow condition code
//      unsigned int N : 1; // ALU negative condition code
//      unsigned int C : 1; // ALU carry condition code
//      unsigned int Z : 1; // ALU zero condition code
//      unsigned int MV : 1; // MDU overflow condition code
//      unsigned int MN : 1; // MDU negative condition code
//      unsigned int MC : 1; // MDU carry condition code
//      unsigned int MZ : 1; // MDU zero condition code
//      unsigned int MB : 1; // MDU busy flag
//      unsigned int SMCLK : 1; // semaphore locked flag
// } register_cc;
```

5.6.7 Built-in / Intrinsic Functions

This section covers available built-in/library/intrinsic functions available in ETEC.

5.6.7.1 Compatibility Functions

The following built-in functions provide user control of eTPU hardware settings & features, but generate no code; they provide compatibility with existing solutions.

match_enable() - when called out in a thread, it causes matches to be enabled during the thread by setting the match enable bit in the entry table for all vectors pointed at the thread. Note that threads default to matches enabled. Not needed in ETEC enhanced mode.

match_disable() - when called out in a thread, it causes matches to be disabled during the thread by setting the match enable bit in the entry table for all vectors pointed at the thread. Note that threads default to matches enabled. Not needed in ETEC enhanced mode.

preload_p01() - when called out in an eTPU-C thread, specifies that the low preload entry option is to be used - this means p gets loaded with the data at channel frame address 0 (32 bits), and diob gets loaded with the data at channel frame address 5 (24 bits). The default is to let the tools decide which preload results in the best code (recommended). In ETEC mode, the preload is specified by specifying a second parameter to the eTPU thread, "_eTPU_preload_low" or "_eTPU_preload_high".

preload_p23() - when called out in an eTPU-C thread, specifies that the high preload entry option is to be used - this means p gets loaded with the data at channel frame address 8 (32 bits), and diob gets loaded with the data at channel frame address 13 (24 bits). The default is to let the tools decide which preload results in the best code (recommended). In ETEC mode, the preload is specified by specifying a second parameter to the eTPU thread, "_eTPU_preload_low" or "_eTPU_preload_high".

Functions that affect code generation:

read_mer() – triggers the contents of the A and B match registers to be transferred into the erta/ertb registers.

NOP() – injects a no-op opcode into the code stream that does not get optimized out.

5.6.7.2 ETEC Coherency & Synchronization Control

These functions allow users to clearly state their needs in terms of coherency, ordering, etc.

_AtomicBegin(), _AtomicEnd() - code located between a pair of these calls will be packed into a single opcode; if this cannot be done a compilation error results. Another side-effect of these atomic regions is that the optimizer will not optimize the code out, or move any of the sub-instructions apart from each other. Other sub-instructions may be optimized into the atomic opcode. See the Atomicity Control section for a matching pragma definition.

Example 1, Coherently clear any old match and schedule a new match,

```
// Coherently clear any old match and schedule a new match
_AtomicBegin();
WriteErtAToMatchAAndEnable();
ClearMatchAEvent();
_AtomicEnd();
```

Example 2, the provided macros for working around the T2/T4 (see provided standard file 'etpu_std.h'):

```
/* eTPU2 unambiguous match set when in T2/T4 timing mode */
#define EnableMatchA_T2T4()      { _AtomicBegin(); channel.
ERWA = 0; channel.MRLEA = 0; _AtomicEnd(); }
```

```
#define EnableMatchB_T2T4()      { _AtomicBegin(); channel.
ERWB = 0; channel.MRLEB = 0; _AtomicEnd(); }
```

_SynchBoundaryAll() – disables any code from moving across the boundary during the optimization process. See the Optimization Boundary (Synchronization) Control section for a matching pragma definition.

Example 3, enforcing order of operations when setting a lock.

```
dataLock = 1;
_SynchBoundaryAll();
*ptr++ = SomeVal;
_SynchBoundaryAll();
dataLock = 0;
```

5.6.7.3 TR18037 Fixed-point Library Support

_Fract support includes a portion of the fixed-point library specified in TR 18037, as well as some extensions. Supported functions are:

int mulir(int, _Fract) – under ordinary arithmetic conversion rules the result of a multiplication of an integer and a _Fract is a _Fract. There are applications where instead the desired result is the integer portion of the result; this library function provides that capability.

unsigned int muliur(unsigned int, unsigned _Fract) – unsigned version.

Other versions to support 8 and 16 bit int-fract multiplication:

int8 muli8r8(int8, fract8);

unsigned int8 muli8ur8(unsigned int8, unsigned fract8);

int16 muli16r16(int16, fract16);

unsigned int16 muli16ur16(unsigned int16, unsigned fract16);

int24 muli24r8(int24, fract8);

unsigned int24 muli24ur8(unsigned int24, unsigned fract8);

int24 muli24r16(int24, fract16);

unsigned int24 muli24ur16(unsigned int24, unsigned fract16);

5.6.7.4 ALU/MDU Intrinsics

The eTPU has a number of hardware features that are not directly accessible via standard C syntax. The intrinsics defined here provide C function-like access to these capabilities. The eTPU Reference Manual should be consulted for additional details, particularly as related to condition code calculations.

5.6.7.4.1 Rotate Right Support

```
// Rotate right by 1 bit the lower 8 bits
// ( result[6:0] = v[7:1]; result[7] = v[0];
//   result[23:8] = v[23:8]; )
// Condition code flags are sampled on 8 bits.
int24 __rotate_right_1_b7_0(int24 v);
// Rotate right by 1 bit the lower 16 bits
// ( result[14:0] = v[15:1]; result[15] = v[0];
//   result[23:16] = v[23:16]; )
// Condition code flags are sampled on 16 bits.
int24 __rotate_right_1_b15_0(int24 v);
// Rotate right by 1 bit all 24 bits
// ( result[22:0] = v[23:1]; result[23] = v[0]; )
// Condition code flags are sampled on 24 bits.
int24 __rotate_right_1(int24 v);
// Rotate the 24-bit value v
// to the right by 2^(bitexp+1) bits,
// where bitexp can be
// 0, 1, 2 or 3.
// Condition code flags are sampled
// per _sfXX extension, if used.
// See eTPU reference manual for details
// on condition code computation
// with multi-bit rotate.
int24 __rotate_right_2n(int24 v, int24 bitexp);
int24 __rotate_right_2n_sf8(int24 v, int24 bitexp);
int24 __rotate_right_2n_sf16(int24 v, int24 bitexp);
int24 __rotate_right_2n_sf24(int24 v, int24 bitexp);
```

5.6.7.4.2 Absolute Value Support

```
// Compute the absolute value of v.
// Condition code flags are sampled
// per _sfXX extension, if used.
// See eTPU reference manual for details
// on condition code computation with absolute value.
int24 __abs(int24 v);
int24 __abs_sf8(int24 v);
int24 __abs_sf16(int24 v);
int24 __abs_sf24(int24 v);
```

5.6.7.4.3 Shift Register Support

```
// Shift the SR register right one bit.
void __shift_right_SR();
// Shift v right by one bit and return it.
// Register SR also gets shifted right by one
// bit and SR bit 23 gets the bit shifted out of v.
// Condition code flags are sampled
// per _sfXX extension, if used.
// See eTPU reference manual for details
// on condition code computation with add/shift right
int24 __shift_right_SR48(int24 v);
int24 __shift_right_SR48_sf8(int24 v);
int24 __shift_right_SR48_sf16(int24 v);
int24 __shift_right_SR48_sf24(int24 v);
```

5.6.7.4.4 Shift By 2(N+1) Support

```
// Shift 24-bit value v left or right by 2^(bitexp+1) bits,
// where bitexp can be
// 0, 1, 2 or 3.
// Condition code flags are sampled
// per _sfXX extension, if used.
// See eTPU reference manual for details
// on condition code computation with multi-bit rotate.
int24 __shift_left_2n(int24 v, int24 bitexp);
int24 __shift_left_2n_sf8(int24 v, int24 bitexp);
int24 __shift_left_2n_sf16(int24 v, int24 bitexp);
int24 __shift_left_2n_sf24(int24 v, int24 bitexp);
int24 __shift_right_2n(int24 v, int24 bitexp);
int24 __shift_right_2n_sf8(int24 v, int24 bitexp);
int24 __shift_right_2n_sf16(int24 v, int24 bitexp);
int24 __shift_right_2n_sf24(int24 v, int24 bitexp);
```

5.6.7.4.5 Set/Clear Bit Support

```
// Set or clear (bitval==0 -> clear, bitval==1 -> set)
// the bit specified by bitnum in v.
// If revbitnum is not equal to 0,
// then the updated bit is actually 31 - bitnum.
// Condition code flags are sampled per _sfXX extension,
// if used.
// See eTPU reference manual for details on condition code
// computation with bit set/clear.
int24 __bit_n_update(int24 v, int24 bitnum,
                     int bitval, int revbitnum);
int24 __bit_n_update_sf8(int24 v, int24 bitnum,
                         int bitval, int revbitnum);
int24 __bit_n_update_sf16(int24 v, int24 bitnum,
                          int bitval, int revbitnum);
int24 __bit_n_update_sf24(int24 v, int24 bitnum,
                          int bitval, int revbitnum);
```

5.6.7.4.6 Exchange Bit Support

```
// Exchange the bit in v specified by the bitnum
// with C condition code flag.
// If revbitnum is not equal to 0, then the updated bit
// is actually 31 - bitnum rather then bitnum.
// Condition code flags are sampled per _sfXX extension,
// if used.
// See eTPU reference manual for details on condition code
// computation with bit exchange.
int24 __bit_n_exchange_C(int24 v, int24 bitnum,
                         int revbitnum);
int24 __bit_n_exchange_C_sf8(int24 v, int24 bitnum,
                             int revbitnum);
int24 __bit_n_exchange_C_sf16(int24 v, int24 bitnum,
                              int revbitnum);
int24 __bit_n_exchange_C_sf24(int24 v, int24 bitnum,
                              int revbitnum);
```

5.6.7.4.7 MAC/MDU Support

All MAC/MDU intrinsic functions include a spin-while-busy loop after the operation is begun. The optimizer will attempt to fill the pipeline with non-dependent opcodes and eliminate the spin loop.

```
// Signed multiplication, with second argument 8, 16, or 24 bit
// {mach,macl} = x * y
void __mults8(int24 x, int8 y);
void __mults16(int24 x, int16 y);
void __mults24(int24 x, int24 y);
// Unsigned mutliplication, with second argument 8, 16, or 24 bit
void __multu8(unsigned int24 x, unsigned int8 y);
void __multu16(unsigned int24 x, unsigned int16 y);
void __multu24(unsigned int24 x, unsigned int24 y);
// Signed 24-bit multiply-accumulate.
// {mach,macl} += x * y
void __macs(int24 x, int24 y);
// Unsigned 24-bit multiply-accumulate.
// {mach,macl} += x * y
void __macu(unsigned int24 x, unsigned int24 y);
// Multiply signed value x and unsigned 8-bit fractional value f.  The
mantissa
// portion of the result ends up in mach, and the fractional portion ends up
in macl.
void __fmults8(int24 x, unsigned fract8 f);
// Multiply signed value x and unsigned 16-bit fractional value f.  The
mantissa
// portion of the result ends up in mach, and the fractional portion ends up
in macl.
void __fmults16(int24 x, unsigned fract16 f);
// Multiply unsigned value x and unsigned 8-bit fractional value f.  The
mantissa
// portion of the result ends up in mach, and the fractional portion ends up
in macl.
void __fmultu8(unsigned int24 x, unsigned fract8 f);
// Multiply unsigned value x and unsigned 16-bit fractional value f.  The
mantissa
// portion of the result ends up in mach, and the fractional portion ends up
in macl.
void __fmultu16(unsigned int24 x, unsigned fract16 f);
// Unsigned division, 24 bit / 8,16,24 bit
// {macl} = x / y, {mach} = remainder
void __divu8(unsigned int24 x, unsigned int8 y);
void __divu16(unsigned int24 x, unsigned int16 y);
void __divu24(unsigned int24 x, unsigned int24 y);
```

5.7 Code Fragments

Given the thread-based nature of eTPU execution, ETEC provides the concept of "no-return" function calls – such functions are called "fragments" and are specified by using the special return type "_eTPU_fragment". Give the no-return functionality, _eTPU_fragment is essentially equivalent to the void type.

When a call to a fragment is made, the compiler generates a jump opcode rather than a call opcode since no return occurs. Additionally, no state such as registers, stack frame, etc. is saved since execution cannot return to the caller, thereby saving unnecessary overhead. Fragments support passing parameters just like normal functions, and the calling conventions are the same except for the state save (on both caller and callee sides). Note that on the fragment (callee) side, there is also reduced state saving – non-volatile registers do not need to be saved, nor does the return address register. Internally, fragments work just like any other C function – they can make calls, even to other fragments. A simple example of using common initialization code is show below.

```
_eTPU_thread PPA::INIT_TCR1(_eTPU_matches_disabled)
{
    /* set up time base for TCR1*/
    ActionUnitA( MatchTCR1, CaptureTCR1, GreaterEqual);
    CommonInit();  // no return from this call
}

_eTPU_thread PPA::INIT_TCR2(_eTPU_matches_disabled)
{
    /* set up time base for TCR2 */
    ActionUnitA( MatchTCR2, CaptureTCR2, GreaterEqual);
    CommonInit();  // no return from this call
}

_eTPU_fragment PPA::CommonInit()
{
    DisableOutputBuffer(); /* required for Puma */

    // Needed so ouptut pin does not get toggled
    OnMatchA(NoChange);

    // Needed so ouptut pin does not get toggled
    OnMatchB(NoChange);

    ClearAllLatches();
    Measurement = Inactive;

    // Enable service request when first edge occurs
    SingleMatchSingleTransition();

    // ...
}
```

Note that the compiler will attempt to detect stranded code that follows a call to a fragment, and issue a warning if it finds such code.

The ETEC compiler supports an alternative syntax for fragment declarations. The "_eTPU_fragment" keyword can be used interchangeably with "void __attribute__ ((noreturn))", which is a GNU-based syntax.

5.7.1 _eTPU_thread Calls

ETEC supports “calls” to _eTPU_thread functions – these act like calls to fragments in that they execute a jump rather than call. Although this is functional, in most cases it is recommended that such common code be placed in an _eTPU_fragment instead and called from two locations, rather than directly calling an _eTPU_thread. Threads (_eTPU_thread functions) may contain additional prologue code that the caller does not actually want to execute, although such code does not cause invalid behavior.

5.8 State Switch Constructs

ETEC provides a specialized version of the C switch statement that provides reduced thread length operation and in most cases reduced code size, at the cost of user control over state values and some of the robustness features of the standard C switch statement. The tradeoffs should be carefully considered before choosing to use this feature. This ‘state switch’, as it is referred to, makes efficient use of the eTPU architecture’s dispatch instruction. The dispatch instruction allows a jump (or call) to the instruction at the address of the current program counter, plus a variable displacement which can be up to 255 instructions/opcodes. This feature is activated through two new keywords:

```
// similar to “switch” keyword in C syntax
_eTPU_state_switch
// similar to “enum” keyword in C syntax
_eTPU_state_switch_enum
```

The sections below provide the details on this feature.

5.8.1 State Enumeration

A state enumeration must be declared as only expressions of this type may be used in state switches. A state enumeration is like a regular ‘C’ enum, with a few of exceptions.

- A state enumeration is denoted with the ‘_eTPU_state_switch_enum’ rather than ‘enum’ keyword.
- The enumerators in a state enumeration cannot be assigned values. Code such “_eTPU_state_switch_enum CrankState { STALL = 5, };” will result in a compile error.
- The enumerator values assigned by the compiler/linker may not match the ANSI standard for C code, wherein they start at 0, and increment by 1 with each successive enumerator. Rather, the compiler/linker assigns values such that the dispatch instruction used for the matching _eTPU_state_switch works correctly.
- _eTPU_state_switch_enum tag types (or typedef thereof) cannot be used in typecasts. This is to prevent potentially dangerous code.
- Variables declared with an _eTPU_state_switch_enum tag type are always allocated as a single unsigned byte.
- State enumeration literals must be unique among all the enumeration literals (state or regular) of all the code that is to be linked together. This limitation is due to the fact that the enumeration literals only get computed at link time and if the literals are not uniquely named there can be clashes.

An example of a state enumeration type declaration is as follows:

```
_eTPU_state_switch_enum CrankStates
{
   CRANK_SEEK,
   CRANK_BLANK_TIME,
   CRANK_BLANK_TEETH,
   CRANK_FIRST_EDGE,
   CRANK_SECOND_EDGE,
   CRANK_TEST_POSSIBLE_GAP,
   CRANK_VERIFY_GAP,
   CRANK_GAP_VERIFIED,
   CRANK_COUNTING,
   CRANK_TOOTH_BEFORE_GAP,
   CRANK_TOOTH_AFTER_GAP,
        CRANK_TOOTH_AFTER_GAP_NOT_HRM
    };
```

5.8.2 State Variable

A “state” variable must be declared with a state enumeration type. Variables of this special tag type are 1 byte in size, and unlike variables of the standard enum tag type, strict type checking is performed by the compiler. Such a state variable cannot be assigned to a constant integer value, for example, or assigned the value of another variable of integer type. It can only be assigned to one of the _eTPU_state_switch_enum enumerators, or to another variable of exactly the same type.

```
    // declare state variable
    _eTPU_state_switch_enum CrankStates Crank_State;

    // compilation error – must assign to an enumerator
    Crank_State = 0;

    // valid
    Crank_State = CRANK_SEEK;
```

5.8.3 State Switch

For each _eTPU_state_switch_enum tag type there can be up to one _eTPU_state_switch statement. It is the contents of this statement that determine the state (enumerator) values. The linker issues an error if it finds more than one _eTPU_state_switch associated with the same _eTPU_state_switch_enum tag type. Statements denoted with _eTPU_state_switch are very much like the standard ‘C’ switch statement, with a few exceptions:

- The controlling expression in an _eTPU_state_switch statement must have an _eTPU_state_switch_enum tag type.
- No ‘default’ case is allowed in an _eTPU_state_switch.
- All enumerators in the _eTPU_state_switch_enum tag type used in the controlling expression must be associated with a case, even if it does nothing but ‘break’.
- When multiple cases are associated with the same piece of code, the compiler implicitly inserts a NOP() between them – it must do this to ensure that each enumerator is the _eTPU_state_switch_enum tag type gets a unique value.

- No range or validity check is done on the controlling expression value. Programmers using this feature MUST ensure that the state variable does not get assigned an invalid value. The compiler assists with this via its strict type checking on _eTPU_state_switch_enum tag types.

Note that a state variable, although it can only be used in a single _eTPU_state_switch statement, can be used other places in a normal 'C' switch statement.

An example of a state switch, shown in a listing file, is shown below (some code removed for brevity). Note that every enumerator is covered by a case, and note the NOPs inserted where multiple cases fall through to the same code.

```
                    _eTPU_state_switch (Crank_State)
0CF4: 0xCFEFF987   ram   p_31_24 = *((channel int8 *) 0x1C);;
0CF8: 0xFFDFDEF9   seq  goto ProgramCounter + p_31_24, flush;;
                       {
                       case CRANK_BLANK_TIME:
                           // timeout is expected
                           Blank_Time_Expired_Flag = 1;
0CFC: 0x000FA439   alu     p_31_24 = ((u24) 0)+0x1;;
0D00: 0xCFFFF986   ram    *((channel int8 *) 0x18) = p_31_24;;
                           // Timeout time
                           ertb = Tooth_Time + Blank_Time;
0D04: 0xBFEC2F87   alu     ertA = tcr1+0x0;
    :              ram    diob = *((channel int24 *) 0x1D);;
0D08: 0x1F783FFF   alu     ertB = p+diob;;
                           // schedule an immediate match to open the window
                           erta = tcr1;
                           ClearMatchALatch();
0D0C: 0x58FFFE1F   chan    clear MatchRecognitionLatchA, matchA = ertA,
                           set MatchEnableLatchA,
                           clear MatchRecognitionLatchB,
                           matchB = ertB, set MatchEnableLatchB,
    :                      detectA = off;;
                           ClearMatchBLatch();
                           WriteErtAToMatchAAndEnable();
                           WriteErtBToMatchBAndEnable();
                           // don't detect transition during blank time
                           OnTransA (NoDetect);
                           tcr2 = 0;
0D10: 0x0FFF9FFF   alu     tcr2 = ((u24) 0)+0x0;
    :              seq    end;;
                           break;

                       case CRANK_BLANK_TEETH:
                           // schedule an immediate match
                           // to open the window
                           erta = tcr1;
```

```
                                 // clear MatchB
                                 // & don't set new match value
                                 ClearMatchBLatch ();
0D14: 0xDFEFD984   ram   p_31_24 = *((channel int8 *) 0x10);
    :              chan  clear MatchRecognitionLatchB;;
                                 // so it always enabled window is fully open
                                 // MatchA is left pending;
                                 // in this channel mode
                                 // it doesn't request service
                                 Blank_Tooth_Count--;
0D18: 0x1EF2AFFF   alu    p_31_24 = p_31_24-0x0-1;;
0D1C: 0xCFFFF984   ram   *((channel int8 *) 0x10) = p_31_24;;

// < REMOVED>

                             case CRANK_FIRST_EDGE:
                                 // Timeout time
                                 ertb = Tooth_Time + First_Tooth_Timeout;
0D34: 0xBFEF9F89   alu    tcr2 = ((u24) 0)+0x0;
    :              ram   diob = *((channel int24 *) 0x25);;
0D38: 0x1F783FFF   alu    ertB = p+diob;;
                                 WriteErtBToMatchBAndEnable();
0D3C: 0x7FFFFF9F   chan  clear MatchRecognitionLatchB, matchB = ertB,
                                 set MatchEnableLatchB;;
                                 ClearMatchBLatch();
                                 Crank_State = CRANK_SECOND_EDGE;
0D40: 0x005FA439   alu    p_31_24 = ((u24) 0)+0x15;;
0D44: 0xCFFFF987   ram   *((channel int8 *) 0x1C) = p_31_24;;
                                 tcr2 = 0;

// <REMOVED>

                             case CRANK_SECOND_EDGE:
                                 Tooth_Period_A = Tooth_Time - Last_Tooth_Time;
0D50: 0xBFEF9F95   alu    tcr2 = ((u24) 0)+0x0;
    :              ram   diob = *((channel int24 *) 0x55);;
0D54: 0xBC787B91   alu    p = p-diob;
    :              ram   *((channel int24 *) 0x45) = p_23_0;;
                                 Crank_State = CRANK_TEST_POSSIBLE_GAP;
0D58: 0x009FA459   alu    p_31_24 = ((u24) 0)+0x26;;
0D5C: 0xCFFFF987   ram   *((channel int8 *) 0x1C) = p_31_24;;
                                 tcr2 = 0;

// <REMOVED>

                             case CRANK_TEST_POSSIBLE_GAP:
                                 Tooth_Period_B = Tooth_Time - Last_Tooth_Time;
0D94: 0xBFEFFF95   ram   diob = *((channel int24 *) 0x55);;
0D98: 0xBC787B93   alu    p = p-diob;
```

```
            :               ram   *((channel int24 *) 0x4D) = p_23_0;;

        // <REMOVED>

                               case CRANK_VERIFY_GAP:
                                   Tooth_Period_A = Tooth_Time - Last_Tooth_Time;
        0E4C: 0xBFEFFF95   ram   diob = *((channel int24 *) 0x55);;
        0E50: 0xBC787B91   alu    p = p-diob;
            :               ram   *((channel int24 *) 0x45) = p_23_0;;
                                   // Gap is verified
                                   if ( muliur(Tooth_Period_B, Gap_Ratio)
                                            > Tooth_Period_A)
        0E54: 0xBFEFFB93   ram   p_23_0 = *((channel int24 *) 0x4D);;
        0E58: 0xBFEFFF86   ram   diob = *((channel int24 *) 0x19);;
        0E5C: 0x2F78FFE9   alu    mac = p * ((u24) diob);;
        0E60: 0xF3587307   seq  if MacBusy==true then goto 0xE60, flush;;
        0E64: 0xBFEFFB91   ram   p_23_0 = *((channel int24 *) 0x45);;
        0E68: 0x1C17FEEF   alu    nil = mach-p, SampleFlags;;
        0E6C: 0xF4D87607   seq  if LowerOrEqual==true then goto 0xEC0, flush;;
                                     {
                                         Crank_State = CRANK_GAP_VERIFIED;
        0E70: 0x01FFA459   alu    p_31_24 = ((u24) 0)+0x7E;;
        0E74: 0xCFFFF987   ram   *((channel int8 *) 0x1C) = p_31_24;;

        // <REMOVED>

                               case CRANK_GAP_VERIFIED:
                                   Tooth_Count++;
        0EF4: 0xCFEB3980   ram   p_31_24 = *((channel int8 *) 0x0);
            :               chan  set ChannelFlag1, set SvcdChan ChannelIntr;;
        0EF8: 0x0002A439   alu    p_31_24 = p_31_24+0x1;;
        0EFC: 0xCFFFF980   ram   *((channel int8 *) 0x0) = p_31_24;;

        // <REMOVED>

                               case CRANK_SEEK:
        0F40: 0x4FFFFFFF   nop;;
                               case CRANK_COUNTING:
        0F44: 0x4FFFFFFF   nop;;
                               case CRANK_TOOTH_BEFORE_GAP:
        0F48: 0x4FFFFFFF   nop;;
                               case CRANK_TOOTH_AFTER_GAP:
        0F4C: 0x4FFFFFFF   nop;;

                               case CRANK_TOOTH_AFTER_GAP_NOT_HRM:
                                   Error_Status = Error_Status
                                                |  CRANK_INTERNAL_ERROR;
        0F50: 0xCFEFF982   ram   p_31_24 = *((channel int8 *) 0x8);;
        0F54: 0x0C42AB82   alu    p_31_24 = p_31_24 | 0x10;;
```

```
0F58: 0xC7FFF982   ram   *((channel int8 *) 0x8) = p_31_24;
    :              seq   end;;
                          break;
                      }
```

5.8.4 Additional Notes

The compiler/linker calculated state enumeration values are output through all the supported host interface mechanisms. For example, given the examples above, this is what is output for the CrankStates state enumeration:

```
// defines for type _eTPU_state_switch_enum CrankStates
// size of a tag type
// value (sizeof) = _CHAN_TAG_TYPE_SIZE_CrankStates_
#define _CHAN_TAG_TYPE_SIZE_CrankStates_ 0x01
// values of the literals of an enum type
// value = _CHAN_ENUM_LITERAL_Crank_CrankStates_CRANK_SEEK_
#define _CHAN_ENUM_LITERAL_Crank_CrankStates_CRANK_SEEK_ 0x91
#define _CHAN_ENUM_LITERAL_Crank_CrankStates_CRANK_BLANK_TIME_ 0x00
#define _CHAN_ENUM_LITERAL_Crank_CrankStates_CRANK_BLANK_TEETH_ 0x06
#define _CHAN_ENUM_LITERAL_Crank_CrankStates_CRANK_FIRST_EDGE_ 0x0E
#define _CHAN_ENUM_LITERAL_Crank_CrankStates_CRANK_SECOND_EDGE_ 0x15
#define _CHAN_ENUM_LITERAL_Crank_CrankStates_CRANK_TEST_POSSIBLE_GAP_ 0x26
#define _CHAN_ENUM_LITERAL_Crank_CrankStates_CRANK_VERIFY_GAP_ 0x54
#define _CHAN_ENUM_LITERAL_Crank_CrankStates_CRANK_GAP_VERIFIED_ 0x7E
#define _CHAN_ENUM_LITERAL_Crank_CrankStates_CRANK_COUNTING_ 0x92
#define _CHAN_ENUM_LITERAL_Crank_CrankStates_CRANK_TOOTH_BEFORE_GAP_ 0x93
#define _CHAN_ENUM_LITERAL_Crank_CrankStates_CRANK_TOOTH_AFTER_GAP_ 0x94
#define _CHAN_ENUM_LITERAL_Crank_CrankStates_CRANK_TOOTH_AFTER_GAP_NOT_HRM_
0x95
```

If the code that makes up the state switch exceeds 255 opcodes, there may be some cases that still require the dispatch jump plus a regular jump. Such cases can be minimized but putting the most code-intensive case(s) at the end of the state switch.

The user can easily convert ETEC-specific state switch code to ANSI-compliant code by utilizing macros such as:

```
        #define _eTPU_state_switch switch
        #define _eTPU_state_switch_enum enum
```

5.9 eTPU Constant Tables

The eTPU instruction set provides a fairly efficient way to create 24-bit constant lookup tables in the code. These special lookup tables are not any more efficient than the use of a regular C arrays for lookup tables, and in fact access is almost always slightly slower. However, they do offer one key difference that can be advantageous in some cases - the constant table is stored in the code memory rather than the data memory. If system being programmed is out of data memory (SDM), but is not using all of code memory (SCM), then the use of this constant lookup table construct can be very helpful. Below, the syntax and usage is described. For much more detail on eTPU constant lookup tables, including how to perform run-time data calibration, please see the Assembler Reference Manual Constant Lookup Table section.

In C code, constant tables are defined as arrays of the special type '_eTPU_constant_table'. The arrays can be multi-dimensional. Typically an initializer should be used to load the constant table. Any uninitialized array elements are given a value of 0. When a 24-bit value is retrieved from the table, it is treated as a signed integer by default. Type casting can be used to change to unsigned, _Fract (fractional), or whatever type is desired.

```
// constant table definition (global)
_eTPU_constant_table sin_table[64] = { 0x000000,
0x034517, ... };

// external declaration for reference from other files
extern _eTPU_constant_table sin_table[64];

// multi-dimensional
_eTPU_constant_table switch_table[2][2] = { { 3, 2, }, { 1,
0 } };

// table static to a scope
static _eTPU_constant_table coef_table[8] = { 0x0,
0x200, ... };
```

Syntactically, accessing elements of the table is handled just like normal array element access.

```
int coef = coef_table[index]; // get the coefficient
specified by index
fract24 sin_val = (fract24)sin_table[angle];
```

Because constant tables exist in code memory which is not writeable and utilize a special eTPU microcode instruction, there are several limitations associated with them:

- tables can contain at most 256 elements

- because the table lives in immutable, inaccessible code memory, the only operation that can be performed on the table symbol is a full array de-reference. No conversion to a pointer or other operations.

- tables can only be defined at global scope, or static to a function scope

5.10 ETEC Local Variable Model & Calling Conventions

When local variables are declared & used, they are allocated to available registers if possible, but the resources are limited. The same situation arises when function calls with parameters are made – some parameters may be passed by registers but again it is a very limited resource on the eTPU. Thus local variables, parameters, and other data that needs to be saved/restored on function calls must be kept somewhere in memory. The default model that ETEC uses for this is a stack that builds upwards in memory as function call-tree depth increases.

The stack approach allows any C code to compile and run without fail (within memory limits), but in some cases may not generate as optimal code as that compiled using a "scratchpad" model. ETEC supports "–globalScratchpad" "-engineScratchpad" options to enable compilation with this model. When scratchpad is enabled and data overflows registers, rather than go onto a dynamic stack, it is allocated to static addresses in global memory (engine relative available on the eTPU2). While generally less efficient with regards to memory usage than a stack solution, the eTPU instruction set is such that the resulting code tends be slightly more efficient in size and performance. The greatest weakness of this solution is that it can lead to a very insidious bug in the original eTPU (or whenever global scratchpad is used) – when the same function runs simultaneously on both eTPUs of a dual-eTPU engine micro, and the function uses scratchpad memory, there can be corruption/coherency issues as both eTPUs simultaneously use the same scratchpad memory. Users of the global scratchpad model must be very careful to use functions that access scratchpad on only one eTPU at a time.

Both models are discussed in further details in the sections below. Note that source compiled to different models can be linked successfully, it is recommended that for most cases one model or the other should be chosen for all code that is to be linked into an executable image.

5.10.1 Stack-based Model

ETEC uses a stack-based approach for local variables and function calls by default. Any eTPU threads / functions for which local variables overflow register availability, or perform function calls, reference a stack base variable. This stack base parameter is allocated as a channel variable in the function's (class') channel frame, and thus each channel with a function that uses the stack has a stack base parameter that must be initialized when the rest of the channel is initialized. Note that channels on each eTPU should share the same stack base, which is a byte address in the eTPU SDM address space. On a dual eTPU system, each eTPU engine must have unique stack base addresses.

On the eTPU, on a dual engine system, the SDM layout may look as follows:

global variables start at address 0
engine 0 stack
engine 1 stack
engine 0, channel 0 channel variables
engine 0, channel 1 channel variables   *[including compiler allocated stack base to be filled in during host eTPU initialization]*
engine 0, channel 5 channel variables
….
engine 1, channel 0 channel variables
engine 1, channel 3 channel variables

[including compiler allocated stack base to be filled in during host eTPU initialization]
….
engine 1, channel 27 channel variables

On the eTPU2, the SDM layout may look something like the following if there is user-defined engine relative data:

global variables start at address 0
engine-space variables (engine 0) *user engine data*
engine-space variables (engine 1) *user engine data*
engine 0 stack
engine 1 stack
engine 0, channel 0 channel variables
engine 0, channel 1 channel variables *[including compiler allocated stack base to be filled in during host eTPU initialization]*
engine 0, channel 5 channel variables

….
engine 1, channel 0 channel variables
engine 1, channel 3 channel variables   *[including compiler allocated stack base to be filled in during host eTPU initialization]*
….
engine 1, channel 27 channel variables

5.10.2 Calling Convention

The stack-based programming model uses registers, and if necessary stack-space, to pass parameters when function calls are made. Stack is also used to save function state such as volatile registers that are in use at the time of the call. The detailed calling convention procedure is outlined below:

- First, any volatile registers that are in use at the time of the function call are saved onto the stack, if any. Volatile registers are: P, A, SR, MACH, MACL. The exception to this are named register variables. The registers used for such variables are not saved and restored during a function call, which allows for implicit parameter passing via register (as is done in some legacy applications).
- Next, if the stack frame offset is changing (the stack is used by the current function for local variables, or any volatile registers have been saved), the current stack frame (register B) is saved to the stack.
- At this point the current stack pointer is the stack frame for the called function.
- The arguments to the function are processed. The first argument that can fit in a 24-bit register is allocated to the A register. The next argument that can fit in a register is allocated to the SR register. Finally, the next argument that can fit in a register is allocated to the MACL register. Any further arguments, or those that do not fit in a register (e.g. a structure larger than 24-bits), are placed on the stack

in order.

- The stack frame (register B) is updated to the new value if necessary, and the call is made. Note that if the called function has a return type/value that fits in a register, it will be returned in register A. Otherwise, space is allocated on the stack after the parameters.
- On the callee side, the following is done.
- If the callee itself makes further function calls, it saves the RAR (return address) register onto the stack.
- If the function uses any of the non-volatile registers (registers C and D), it saves them to the stack.
- Last, passed parameters are moved to their final locations, if they are different. For example, a parameter passed via register may get allocated to a stack location, or a parameter passed on the stack may be moved to a register.

Based on the sample code below:

```
struct S { int x, y; };

… (in a function)
char a;
struct S b;
int c, d, e;
struct S f = CalcPos(a, b, c, d, e);
… (rest of function)

struct S CalcPos(char a, struct S b, int c, int d, int e)
{
…
   return b;
}
```

The resulting stack may look like:

caller SF + N + 0 : register A saved (for example's sake, it was in use at time of call)
caller SF + N + 4 : current stack frame saved

**** NEW CALLEE STACK FRAME ****
callee SF + 0 : parameter ‘b’
callee SF + 4 : parameter ‘b’ continued
callee SF + 8 : parameter ‘e’
callee SF + 12 : return value location
callee SF + 16 : return value location continued
callee SF + 20: register RAR saved
callee SF + 24 : register D saved
callee SF + 28 : register C saved
callee SF + 32 : parameter ‘a’ moved from register A to this stack location
… any additional callee stack usage starts here …

Note that in most real eTPU code, much less stack space is required for a function call (good eTPU code should not pass & return structures).

The ETEC compiler pre-defines a macro __ETEC_EABI_STACK_V1_0__ when the above calling convention is in use. Should the calling convention ever change in future versions of the compiler, this macro’s version number will also be changed. This allows users who write code (e.g. inline assembly) that depends upon the calling convention to detect a change and prevent to possible compilation of non-function code.

5.10.3 Scratchpad-based Model

When the scratchpad-based model is enabled, local variables that overflow register availability, and function state that needs to be saved when function calls are made (including parameters) get allocated in what is called “scratchpad” space. On the eTPU, scratchpad is just global memory, placed after (above) user global variables. When compiled for the eTPU2 target, scratchpad data may be assigned to engine-relative space rather than global address space. Each eTPU2 engine sees its own independent engine-relative space; the global location of these engine-relative spaces is configured via a host CPU register. One down-side of the eTPU2 engine-relative space is that it can only be configured to begin on 256-byte boundaries, and thus may result in wasted Shared Data Memory (SDM). Additionally, in some cases engine-relative memory accesses are less efficient than global address accesses. If the protection provide by engine-relative addressing on a dual-eTPU is not needed, it is not recommended that it be used.

On the eTPU (or when –globalScratchpad is specified on the eTPU2), the SDM layout looks essentially the same whether it is a single or dual-engine part:

global variables start at address 0
global scratchpad allocation
engine 0, channel 0 channel variables
engine 0, channel 1 channel variables
engine 0, channel 5 channel variables
….
engine 1, channel 0 channel variables
engine 1, channel 3 channel variables
….

engine 1, channel 27 channel variables

On the eTPU2, there is one engine space allocated per engine, and the scratchpad can be allocated out of this address space if specified with the "-engineScratchpad" option. The diagram below shows an example SDM layout for a dual-engine target. Note that the engine space allocations could be anywhere in memory, with the only limitation being they begin on a 256-byte boundary.

global variables start at address 0
engine 0 engine-relative space *user engine-relative data* *engine-relative scratchpad*
engine 1 engine-relative space *user engine-relative data* *engine-relative scratchpad*
engine 0, channel 0 channel variables
engine 0, channel 1 channel variables
engine 0, channel 5 channel variables
….
engine 1, channel 0 channel variables
engine 1, channel 3 channel variables
….

engine 1, channel 27 channel variables

5.10.4 Calling Convention

The scratchpad-based programming model uses scratchpad space to pass all parameters when function calls are made. Scratchpad is also used to save function state such as volatile registers that are in use at the time of the call. The detailed calling convention procedure is outlined below:

- First, any volatile registers that are in use at the time of the function call are saved into unique scratchpad locations. Volatile registers are: P, A, SR, MACH, MACL. The exception to this are named register variables. The registers used for such variables are not saved and restored during a function call, which allows for implicit parameter passing via register (as is done in some legacy applications).
- The arguments to the function are processed and each is placed into a unique scratchpad location. Note that this scratchpad location is the same for each invocation of the function (thus scratchpad eliminates the ability to use recursion).
- The call is made. Note that if the called function has a return type/value that fits in a register, it will be returned in register A. Otherwise, scratchpad space is allocated
- On the callee side, the following is done.
- If the callee itself makes further function calls, it saves the RAR (return address) register into scratchpad.
- If the function uses any of the non-volatile registers (registers C and D), it saves them to scratchpad.
- Last, passed parameters are moved to their final locations, if they are different than the location via which they were passed. For example, a parameter may be moved to a register.

The ETEC compiler does provide a mechanism that allows users some control as to how parameters are passed. Function parameters can be designated with a named register storage class, and thus the specified parameter will be passed in the specified register.

This capability should be used with caution, however. This capability is available in either the stack-based or scratchpad-based programming model.

The ETEC compiler pre-defines a macro __ETEC_EABI_ SCRATCHPAD _V1_0__ when the above calling convention is in use. Should the calling convention ever change in future versions of the compiler, this macro's version number will also be changed. This allows users who write code (e.g. inline assembly) that depends upon the calling convention to detect a change and prevent to possible compilation of non-function code.

5.11 In-Line Assembly

The ETEC compiler supports an in-line assembly capability. However, it is important to note that whenever C code and assembly are mixed, the potential for buggy code increases. It is recommended that other avenues, such as the use of intrinsic functions, be explored before resorting to inline assembly. That being said, there are times where only inline assembly can solve the problem at hand. This reference manual describes the syntax for specifying inline assembly, but not the actual assembly syntax itself; see the assembler reference manual for those details.

Inline assembly can be specified in one of two ways. Single-line assembly instructions can be packaged in #asm( ):

```
#asm(ram p -> by diob.)
```

For multiple lines of inline assembly, the better technique is to bracket the text with a #asm / #endasm pair:

```
#asm
    /* if (hd_common->timer==HD_TCR1) */
    ram diob <- hd_common.
    alu diob = diob + 0x04.
    ram p31_24 <- by diob++.  // p = timer
    alu nil = p31_24, ccs.
#endasm
```

In either case, C pre-processing is applied to the text just like any other portion of the source. The #asm, #endasm, and #asm() directives do not have to be the first text on a source line, thus they can be used in macros to group sets of inline assembly instructions. Note that the C preprocessor is run in ETPUC mode, and thus treats "#asm" and "#endasm" text special, allowing them to pass as-is within function-like macros.

Inline assembly can make references to C global variables and channel frame variables. References to static symbols can be made in either RAM instructions, or in ALU instructions where a register is getting loaded with an address of a symbol. In these cases, ETEC supports symbol reference expressions of the form <complex symbol reference> [+ offset] [+ offset] […] where items in [] are optional. A complex symbol reference can include the "." and "[]" operators if the symbol is of the appropriate type : struct/union or array. The referenced address must be static.

Assembly and C treat code labels in a similar way. Labels have function scope and thus jumps/gotos outside of the current function scope do not work. C functions can be called from assembly code, and pure assembly "functions" can be called from see (the assembler reference manual contains details on how to create these assembly functions.

The Inline Assembly Porting Guide contains additional detailed information on ETEC's support of inline assembly.

5.11.1 Calling the Error Handler from User Code

The entry points into the error handler are exposed in the eTpu_Lib.h standard header file:

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

In ETEC mode, users can specify these entry points in any of their entry tables. When user code calls one of these, ETEC actually generates a jump opcode under the hood since these "eTPU threads" end with a "seq end" thread exit.

5.12 ETEC Standard Header Files

The ETEC distribution contains three standard header files. ETEC does not implement the C Standard Library. The ETEC standard header files are:

ETpu_Hw.h – contains key programming model definitions required by most code.

ETpu_Std.h – macros built on top of the programming model to make code more readable. Since this includes both ETpu_Hw.h and ETpu_Lib.h, it is the only standard header that actually needs to be included.

ETpu_Lib.h – function prototypes for the built-in "library" functions, including the fixed point library functions.

6

C Preprocessing

In the ETEC compiler toolkit, C preprocessing is performed by a standalone tool called ETEC_cpp.exe. When source code is put through the ETEC compiler, it automatically spawns ETEC_cpp.exe as a process and passes the source through the C preprocessor first.

The following macros are pre-defined in the compilation environment and passed to ETEC_cpp.exe when spawned by ETEC_cc.exe:

__ETEC__

__ETEC_VERSION__ is defined to a text string of the compiler version. The form is <major version>.<minor version><build letter>.

One of __TARGET_ETPU1__, __TARGET_ETPU2__ depending upon the –target option specified.

ETEC_cpp has other pre-defined macros per the C99 specification:

_ **_DATE_** _ The date of translation of the preprocessing translation unit: a character string literal of the form **`"Mmm dd yyyy"`**, where the names of the months are the same as those generated by the **`asctime`** function, and the first character of **`dd`** is a space character if the value is less than 10. If the date of translation is not available, an implementation-defined valid date shall be supplied.

_ **_FILE_** _ The presumed name of the current source file (a character string literal).

_ _LINE_ _ The presumed line number (within the current source file) of the current source line (an integer constant).

_ _STDC_ _ The integer constant **1**, intended to indicate a conforming implementation.

_ _STDC_HOSTED_ _ The integer constant **1** if the implementation is a hosted implementation or the integer constant **0** if it is not.

_ _STDC_VERSION_ _ The integer constant **199901L**.

_ _TIME_ _ The time of translation of the preprocessing translation unit: a character string literal of the form **"hh:mm:ss"** as in the time generated by the **asctime** function. If the time of translation is not available, an implementation-defined valid time shall be supplied.

The ETEC compiler also specifies the "–mode=ETPUC" to ETEC_cpp.exe. This triggers some minor exceptions to regular C preprocessing in order work with existing code better.

ETEC_cpp.exe can be used as a standalone tool to perform C preprocessing. See section 8.1.1 for details on ETEC_cpp.exe command-line options.

7 Auto Header Generation

The linker can generate header files that contains information for the host CPU build. This includes information such as variable offset information, code image information, function number, etc.

The auto-struct header file is generated by default, and provides C structures for the host-side code that overlay the actual memory layout. Auto-struct generation can be disabled.

The auto-defines header file is automatically generated by default (but can be disabled), and the text within the file is generated by concatenating things like the user-assigned function name with the user-assigned variable name. Additionally, the user can specify a global mnemonic that is pre-pended to all generated text for the purpose of avoiding clashes.

7.1 Auto-Struct File

The global memory space, engine memory space (eTPU2 only) and each channel frame are output in the form of structures that from the host-side overlay the corresponding portions of the Shared Data Memory (SDM) between the host CPU and eTPU. These structures allow for simple reading/writing of SDM from the host via structure member references. Note that this file only contains data structures – the auto-defines file contains many other eTPU interface items such as function numbers that are needed. The auto-struct is generated by default, but can be disabled on request via the linker option –

autostruct. By default, the name is the base executable output file name extended by "_struct.h", but the user can also specify a name by supplying it with –autostruct=<auto-struct file name>.

For example, an auto-struct generated from the NXP PWM function may look like:

```
typedef struct
{
        /* 0x0000 */
        etpu_if_sint32                          Period;
        /* 0x0004 */
        etpu_if_sint32                          ActiveTime;
        /* 0x0008 */
        etpu_if_sint32                          Coherent_Period;
        /* 0x000c */
        etpu_if_sint32                          Coherent_ActiveTime;
        /* 0x0010 */
        etpu_if_sint32                          LastFrame;
        /* 0x0014 */
        etpu_if_sint32                          NextEdge;
} etpu_if_PWM_CHANNEL_FRAME_PSE;
```

Assuming in the host code a pointer of type "etpu_if_PWM_CHANNEL_FRAME_PSE" has been initialized correctly (named "etpu_pwm_pse_chan_7" for sake of example), the host code could initiate a coherent update of the PWM signal with code like:

```
etpu_pwm_pse_chan_7->Coherent_Period = new_period_data;
etpu_pwm_pse_chan_7->Coherent_ActiveTime = new_active_time_data;
// set coherent update host service request
```

Additionally, host debugging tools will be able to cleanly see the eTPU data through these structures for an enhanced debugging experience.

7.1.1 24-bit vs. Non-24-bit Accesses

For each memory space (global, engine, channel frames), up to two data overlay structures may be auto-generated. The first is for accessing non-24-bit data, and the other is for accessing 24-bit data. The idea is that the 24-bit data struct will overlay the PSE (parameter sign extended) mirror, which allows easy read/write of 24-bit parameters through 32-bit accesses on the host side. The non-24-bit data struct is meant to overlay the regular SDM (shared data memory) window. One important item to note regarding 24-bit data, is that on readback through the PSE, the data is always sign extended regardless of whether the data type is signed or unsigned. Unsigned data read through the PSE should still have the top 8 bits masked off.

In order to simplify the access of signed and unsigned 24-bit data through the PSE mirror, up to 3 different overlay structures are generated for PSE access. One includes all 24-bit data, while the other two are signed and unsigned only (and are only generated if there is 24-bit signed data, and/or 24-bit unsigned data).

7.1.2 Naming Conventions

The auto-generated structures are typedef'ed to the following names:

```
// global non-24-bit data
etpu_if_GLOBAL_DATA;

// global 24-bit data (PSE access)
etpu_if_GLOBAL_DATA_PSE;

// engine non-24-bit data (eTPU2-only)
etpu_if_ENGINE_DATA;

// engine 24-bit data (eTPU2-only)
etpu_if_ENGINE_DATA_PSE;

// <func/class name> non-24-bit data
etpu_if_<func/class name>_CHANNEL_FRAME;

 // <func/class name> 24-bit data
etpu_if_<func/class name>_CHANNEL_FRAME_PSE;
```

Every data member has one of 6 basic types. Rather than use raw C type names, another naming convention is used. Users of the auto-struct file must provide their own type definitions for these type names.

```
etpu_if_sint8;   // signed 8-bit data
etpu_if_uint8;   // unsigned 8-bit data
etpu_if_sint16;  // signed 16-bit data
etpu_if_uint16;  // unsigned 16-bit data
                 // signed 32-bit data
                 // (also used for 24-bit data)
etpu_if_sint32;
                 // unsigned 32-bit data
                 // (also used for 24-bit data)
etpu_if_uint32;
```

For every auto-struct that is generated, a macro is also defined. The macro is defined to the expected size of the structure. The idea is that the user should use this to perform a run-time check to ensure that the structure is compiling correctly under their host compiler. The auto-naming convention of the macros is as follows:

```
#define etpu_if_GLOBAL_DATA_EXPECTED_SIZE       <size>
#define etpu_if_GLOBAL_DATA_EXPECTED_SIZE_PSE   <size>
#define etpu_if_ENGINE_DATA_EXPECTED_SIZE       <size>
#define etpu_if_ENGINE_DATA_EXPECTED_SIZE_PSE   <size>
#define etpu_if_<func/class name>_CHANNEL_FRAME_EXPECTED_SIZE      <size>
#define etpu_if_<func/class name>_CHANNEL_FRAME_EXPECTED_SIZE_PSE  <size>
```

7.1.3 eTPU Data in Auto-Structs

For eTPU variables of basic type, the variable name is used as-is as the member name in the auto-generated data overlay structure. For example, the NXP PWM function has the following eTPU code that defines its channel frame:

```
void PWM(int8 Flag, int24 Period, int24 ActiveTime,
         int24 Coherent_Period,
         int24 Coherent_ActiveTime )
{
     static int24 LastFrame;
     static int24 NextEdge;
     // …
}
```

As can be seen, the variable names become the member names in the data overlay structure (note that the 8-bit “Flag” variable ends up in the non-24-bit data structure, which is not shown):

```
typedef struct
{
     /* 0x0000 */
     etpu_if_sint32            Period;
     /* 0x0004 */
     etpu_if_sint32            ActiveTime;
     /* 0x0008 */
     etpu_if_sint32            Coherent_Period;
     /* 0x000c */
     etpu_if_sint32            Coherent_ActiveTime;
     /* 0x0010 */
     etpu_if_sint32            LastFrame;
     /* 0x0014 */
     etpu_if_sint32            NextEdge;
} etpu_if_PWM_CHANNEL_FRAME_PSE;
```

The exception to this naming convention is for eTPU data of struct, union or _Bool type – these cases are discussed in the ensuing sections.

Often there are gaps in the data overlay where no named data to be referenced exists. These gaps are filled by appropriately sized unnamed bit-fields.

7.1.4 eTPU Structures/Unions

When eTPU variables of struct or union type are encountered, they are "flattened" by concatenating the variable and member name (or members of there are multiple levels to the struct/union). The original eTPU struct type cannot be re-generated on the host side because eTPU structures can have size and alignment that are not possible to replicate in host code. For example, the global variable definition:

```
struct CBA
{
     char a, b;
     unsigned int c;
} cba;
```

Results in:

```
typedef struct
{
     /* 0x0000 */
     etpu_if_uint8          cba_a;
     etpu_if_uint8 : 8;
     etpu_if_uint8 : 8;
     etpu_if_uint8 : 8;
     /* 0x0004 */
     etpu_if_uint8          cba_b;
     etpu_if_uint8 : 8;
     etpu_if_uint8 : 8;
     etpu_if_uint8 : 8;
} etpu_if_GLOBAL_DATA;
typedef struct
{
     /* 0x0000 */
     etpu_if_uint32         cba_c;
     /* 0x0004 */
     etpu_if_uint32 : 32;
} etpu_if_GLOBAL_DATA_PSE;
```

Unions present additional challenges to auto-struct generation. The algorithm for generating an auto-struct when a union is encountered is as follows. For a given byte address, find the first union member located at that address and use it to determine the auto-struct member name and type. Note that this is done for both the 24-bit pas and the non-24-bit pass. So a union such as:

```
union Utype
{
    signed char s8;
    short s16;
    int s24;
    int32 s32;
} g_u1;
```

Results in:

```
typedef struct
{
    /* 0x0000 */
    etpu_if_sint8         g_u1_s8;
    etpu_if_uint8 : 8;
    etpu_if_sint16        g_u1_s16;
} etpu_if_GLOBAL_DATA;
typedef struct
{
    /* 0x0000 */
    etpu_if_sint32        g_u1_s24;
} etpu_if_GLOBAL_DATA_PSE;
```

Through ordering of the union members, users can potentially get the auto-struct output they are looking for.

Bit-field members present special issues and are discussed in the next section. Note that arrays of struct/union types are not supported at this time.

7.1.5 Arrays in Auto-Structs

Arrays are handled two different ways by auto-struct, depending upon the element type of the array and the packing of the array. If it all possible the array defined in eTPU-space is output into the auto-struct as an array. This can be done when the following conditions are met: (1) the element type is a basic type, and (2) the stride size and element size are the same (exception: an array of 24-bit basic typed elements can be output as an array through the PSE). Here are a few examples of this, compiled with default "packtight" memory-packing options:

```
        char g_a1[4];
        char g_a2[2][2];
```

Yields the following in the auto-struct:

```
             /* 0x00a4 */
             etpu_if_uint8                      g_a1[4];
             /* 0x00a8 */
             etpu_if_uint8                      g_a2[2][2];
```

The memory architecture of the eTPU prevents all array cases being handled as cleanly as the above, unfortunately. In all other cases the array is "flattened" like struct and union type variables are handled. In the array case, the element index gets appended to the base array name. The most typical case where this must be done is when arrays of elements of type struct or union are encountered. The other case is that of "gapped" arrays. Gapped arrays can occur when other memory-packing modes besides "packtight" are used ("fastaccess"). For example, arrays of 8-bit integers get packed in the upper byte of each 4-byte word, leaving 3-byte gaps between elements. These gaps can be filled by other data. When the following declarations are compiled in "fastaccess" mode:

```
        int8 g_s8_array[4];
        int16 g_s16;
```

They yield the following in the auto-struct:

```
        typedef struct
        {
             /* 0x0000 */
             etpu_if_sint8                      g_s8_array_0;
             etpu_if_uint8 : 8;
             etpu_if_sint16                     g_s16;
             /* 0x0004 */
             etpu_if_sint8                      g_s8_array_1;
             etpu_if_uint8 : 8;
             etpu_if_uint8 : 8;
             etpu_if_uint8 : 8;
             /* 0x0008 */
             etpu_if_sint8                      g_s8_array_2;
             etpu_if_uint8 : 8;
             etpu_if_uint8 : 8;
             etpu_if_uint8 : 8;
             /* 0x000c */
             etpu_if_sint8                      g_s8_array_3;
             etpu_if_uint8 : 8;
```

```
                etpu_if_uint8 : 8;
                etpu_if_uint8 : 8;
        } etpu_if_GLOBAL_DATA;
```

In the case of an array of struct type, the declaration below

```
        typedef struct
        {
                unsigned int8 a;
                unsigned int16 b;
                unsigned int24 c;
                unsigned int32 d;

        } S1;
        S1 g_s1[2];
```

generates the following section of auto-struct (non-PSE only; the PSE struct contains the references to member 'c'):

```
                /* 0x0048 */
                etpu_if_uint8                       g_s1_0_a;
                etpu_if_uint8 : 8;
                etpu_if_uint8 : 8;
                etpu_if_uint8 : 8;
                /* 0x004c */
                etpu_if_uint32                      g_s1_0_d;
                /* 0x0050 */
                etpu_if_uint8 : 8;
                etpu_if_uint8 : 8;
                etpu_if_uint16                      g_s1_0_b;
                /* 0x0054 */
                etpu_if_uint8                       g_s1_1_a;
                etpu_if_uint8 : 8;
                etpu_if_uint8 : 8;
                etpu_if_uint8 : 8;
                /* 0x0058 */
                etpu_if_uint32                      g_s1_1_d;
                /* 0x005c */
                etpu_if_uint8 : 8;
                etpu_if_uint8 : 8;
                etpu_if_uint16                      g_s1_1_b;
```

7.1.6 Bit-field and _Bool Variables

Bit-field struct/union members and _Bool variables (_Bool variables can act like bit-fields in that they are assigned to an 8-bit unit, and in some cases, multiple _Bool variable can be packed into different bits of one unit) are handled differently than other members of the auto-struct. One reason for this is that compilers can pack bit-fields in different manners – one way is to pack from the MSB of the enclosing data unit, and the other is to pack from the LSB of the enclosing data unit. The auto-struct capability supports both techniques by enclosing bit-field/_Bool member declarations in conditional compilation clauses controlled by the macros MSB_BITFIELD_ORDER and LSB_BITFIELD_ORDER. The user of the auto-struct header file must define one of these two macros for the code to compile.

```
#if defined(MSB_BITFIELD_ORDER)
                etpu_if_uint8 : 5;
                etpu_if_uint8          _b3 : 1;
                etpu_if_uint8          _b2 : 1;
                etpu_if_uint8          _b1 : 1;
#elif defined(LSB_BITFIELD_ORDER)
                etpu_if_uint8          _b1 : 1;
                etpu_if_uint8          _b2 : 1;
                etpu_if_uint8          _b3 : 1;
                etpu_if_uint8 : 5;
#else
#error Users of auto-struct must define either
MSB_BITFIELD_ORDER or LSB_BITFIELD_ORDER
#endif
```

A second reason for handling bit-fields different from other members of the auto-struct is that host code may need access to the enclosing data unit of the bit-field. This is because writing a bit-field member generates read-modify-write code that is not coherent – this may not be acceptable in some cases. Or, a user may need to write/read multiple bit-fields simultaneously. Thus bit-fields (and _Bools) are placed under a union in the auto-struct, along with the data unit. This union is given an auto-generated name _BF_UNIT_<addr offset>, where <addr offset> is the byte offset within the data overlay segment of the bit-field unit. An entire bit-field unit declaration looks like:

```
     union {
          etpu_if_uint8                _UNIT;
          struct {
#if defined(MSB_BITFIELD_ORDER)
                etpu_if_uint8 : 5;
                etpu_if_uint8          _b3 : 1;
                etpu_if_uint8          _b2 : 1;
                etpu_if_uint8          _b1 : 1;
#elif defined(LSB_BITFIELD_ORDER)
                etpu_if_uint8           _b1 : 1;
                etpu_if_uint8           _b2 : 1;
                etpu_if_uint8           _b3 : 1;
                etpu_if_uint8 : 5;
#else
#error Users of auto-struct must define either
MSB_BITFIELD_ORDER or LSB_BITFIELD_ORDER
#endif
           } _BF;
     } _BF_UNIT_0018;
```

The host could read or write all three bits simultaneously through the construct

```
global_data_ptr->_BF_UNIT_0018._UNIT
```

Individual bits are accessed via constructs like

```
global_data_ptr->_BF_UNIT_0018._BF._b1
```

7.1.7 Example Code

Below is a short sample of code that initializes global memory section data mapping structure pointers, and then accesses eTPU shared code memory via them.

```
// initialize data overlay pointers for global memory
etpu_if_GLOBAL_DATA* GDM = (etpu_if_GLOBAL_DATA*)ETPU_PRAM_BASE;
etpu_if_GLOBAL_DATA_PSE* GDM_PSE = (etpu_if_GLOBAL_DATA_PSE*)
ETPU_PRAM_PSE_BASE;
// check the data overlay structs (auto-struct)
if (sizeof(etpu_if_GLOBAL_DATA) != etpu_if_GLOBAL_DATA_EXPECTED_SIZE)
       return FAIL;
if (sizeof(etpu_if_GLOBAL_DATA_PSE) !=
etpu_if_GLOBAL_DATA_PSE_EXPECTED_SIZE)
       return FAIL;
// write and read some global data
GDM->g_s8 = 0x12;
GDM->g_s16 = 0x1234;
GDM_PSE->g_s24 = 0x123456;
GDM->g_a2[1][1] = 0x34;
if (GDM->g_s1_s8 != (signed char)0x87)
       ErrorEncountered();
if (GDM->g_s1_s16 != (signed short)0x8765)
       ErrorEncountered();
if (GDM_PSE->g_s1_s24 != 0xff876543)
       ErrorEncountered();
```

7.2 Auto-Defines File

The auto-defines header file contains all the compiler-generated information necessary for the host to initialize & control the eTPU, and to place & find data. The contents of this file is explained in detail in the ensuing sections.

7.2.1 Global Prepended Mnemonic

A global mnemonic is prepended to all generated text. The default global mnemonic is the underscore character, '_'. This can be overridden with the linker command line option "-GM=<text>" - see the linker reference manual for more information.

7.2.2 Auto Header File Name

The name of the auto-generated defines header file is the constructed as shown below. This can be overridden using the linker option "-defines=<FileName>" - see the linker reference manual for more details.

```
<ExectutableFileName>_defines.h
```

7.2.3 Text Generation

The purpose of the auto generated text is to produce a series of #defines that are used on the host CPU side code to initialize and run the eTPU function. A series of the #defines are generated that appear as follows.

```
#define <Name> <Value>
```

The <name> is generated by concatenating the global mnemonic, the function or class name (if applicable), the settings mnemonic, and any additional text that is available (such as the variable name.) Additionally, each concatenation is separated by underscores, as follows.

```
_<GlobalMnemonic>_<SettingMnemonic>_><FunctionName>_<Misc>_
```

Note that when the class and the table name are identical then the table name is not included. With regards to variables and their type information, the settings mnemonic is a concatenation of address space and mnemonic.

7.2.4 Type Information

For every variable and tag type member, type information is provided. The possible type values are

```
T_bool
T_sint8
T_uint8
T_sint16
T_uint16
T_sint24
T_uint24
T_sint32
T_uint32
T_sfract8
T_ufract8
T_sfract16
T_ufract16
T_sfract24
T_ufract24
T_ptr
T_array
T_struct
T_union
```

For arrays, the element type is provided, as is done for struct and union members. The base type for pointers is also provided. For both arrays and pointers, the element/base type may be found through multiple dimensions or multiple levels of indirection.

```
#define _GLOB_VAR_TYPE_g_s8_                      T_uint8
#define _GLOB_VAR_TYPE_g_s16_                     T_sint16

#define _CHAN_MEMBER_TYPE_DefinesTest_Stype_s16_  T_sint16
#define _CHAN_MEMBER_TYPE_DefinesTest_Stype_s24_  T_sint24

#define _CPBA_TYPE_DefinesTest__a1_               T_array
#define _CPBA_TYPE_ARRAY_DefinesTest__a1_         T_uint8

#define _GLOB_VAR_TYPE_g_s24_ptr_                 T_ptr
#define _GLOB_VAR_TYPE_PTR_g_s24_ptr_             T_sint24
```

7.2.5 Array Variables

Offsets to variables of array type are output in similar manner to basic type variables, except that the settings mnemonic contains ARRAY (CPBA_ARRAY, ERBA_ARRAY or GLOB_ARRAY). The element typeAdditionally, for each dimension of the array two additional definitions are supplied – the number of elements in the dimension and the stride size. For these <Misc> takes the form <var name>_DIM_<dimension #>_LENGTH and <var name>_DIM_<dimension #>_STRIDE

For example,

```
int24 g_s24_array[10];
```

may yield

```
#define _GLOB_ARRAY_g_s24_array_               0x01
#define _GLOB_ARRAY_g_s24_array_DIM_1_LENGTH   0x10
#define _GLOB_ARRAY_g_s24_array_DIM_1_STRIDE   0x04
```

7.2.6 _Bool Type Variables

Besides the byte offset of the variable's location, _Bool types also list the bit offset within the 8-bit unit of the variable with the mnemonic BOOLBITOFFSET:

```
#define _CPBA8_Test__b4_             0x00
#define _CPBA8_BOOLBITOFFSET__b4_    0x05
```

7.2.7 Struct/Union Variables

Again, offsets to variables of struct/union type are output in a similar manner to other variables. The aggregate type of the variable is encoded in the settings mnemonic.

```
struct S1 g_GlobalStructVar;
union U1 _ChanFrameUnionVar; // in eTPU Function TESTIO
```

The above variable definitions would be exported in the defines file as something like:

```
#define _GLOB_STRUCT_g_GlobalStructVar_       0x10
#define _CPBA_UNION_TESTIO__ChanFrameUnionVar_ 0x05
```

Individual members of these variables can then be located using the additional type information provided, as described in section 6.2.8.

7.2.8 Tag Types (Structures, Unions, Enumerations)

When global (GLOB mnemonic), engine-relative (eTPU2 only, ENG mnemonic) or channel frame (CHAN mnemonic) variables have a tag type, struct, union, or enum, information on that type will be exported in the auto header file. In the case of structs & unions, this information can be used to build up the exact location of each member. Size and alignment information is also included. Two pieces of size data are provided – one is the size that the sizeof() operator would return, which includes any padding in order to reach the array stride size of the struct/union. The second is the raw size used by the structure, and does not include padding. The alignment data indicates the offset, within a 32-bit word, where the struct/union begins. A struct that consists of two 24-bit members would have an alignment of 1, and a raw size of 7. From a host perspective, the number of 32-bit words that must be allocated to hold an eTPU structure is ((<alignment> + <raw size> + 3) >> 2). For example, given the following type definitions:

```
struct S1
{
     int x;
     int y;
};
struct S3
{
     struct S1 s1_1;
     int x;
     char a;
     struct S1 s1_2;
};
```

If used for global variables, this would yield the following in the _defines file:

```
// defines for type struct S1
// size of a tag type
// (including padding as defined by sizeof operator)
// value (sizeof) = _GLOB_TAG_TYPE_SIZE_S1_
#define _GLOB_TAG_TYPE_SIZE_S1_        0x08
// raw size (padding not included) of a tag type
// value (raw size) = _GLOB_TAG_TYPE_RAW_SIZE_S1_
#define _GLOB_TAG_TYPE_RAW_SIZE_S1_    0x07
// alignment relative to a double even address
// of the tag type (address & 0x3)
// value = _GLOB_TAG_TYPE_ALIGNMENT_S1_
#define _GLOB_TAG_TYPE_ALIGNMENT_S1_   0x01
// offset of struct/union members
// from variable base location
// the offset of bitfields is specified in bits,
// otherwise it is bytes
// address = SPRAM + [variable SPRAM offset]
//         + _GLOB_MEMBER_BYTEOFFSET_S1_x_
#define _GLOB_MEMBER_BYTEOFFSET_S1_x_  0x00
#define _GLOB_MEMBER_BYTEOFFSET_S1_y_  0x04
// defines for type struct S3
#define _GLOB_TAG_TYPE_SIZE_S3_        0x14
#define _GLOB_TAG_TYPE_RAW_SIZE_S3_    0x14
#define _GLOB_TAG_TYPE_ALIGNMENT_S3_   0x00
#define _GLOB_MEMBER_BYTEOFFSET_S3_s1_1_ 0x01
#define _GLOB_MEMBER_BYTEOFFSET_S3_x_  0x09
#define _GLOB_MEMBER_BYTEOFFSET_S3_a_  0x00
#define _GLOB_MEMBER_BYTEOFFSET_S3_s1_2_ 0x0D
```

Bitfield member offsets are specified in bits, and also have bit size information:

```
struct S3
{
     struct S1 s1_1;
     int m : 10;
     int n : 10;
     int o : 10; // must go in next "unit"
     int p : 1;
     int q : 1;
     int : 4;
     int r : 1;
     struct S1 s1_2;
};
```

Yields:

```
// defines for type struct S3
#define _CHAN_TAG_TYPE_SIZE_S3_        0x10
#define _CHAN_TAG_TYPE_RAW_SIZE_S3_    0x0F
#define _CHAN_TAG_TYPE_ALIGNMENT_S3_   0x01
#define _CHAN_MEMBER_BYTEOFFSET_Test_S3_s1_1_ 0x00
#define _CHAN_MEMBER_BITOFFSET_Test_S3_m_ 0x4E
#define _CHAN_MEMBER_BITSIZE_Test_S3_m_ 0x0A
#define _CHAN_MEMBER_BITOFFSET_Test_S3_n_ 0x44
#define _CHAN_MEMBER_BITSIZE_Test_S3_n_ 0x0A
#define _CHAN_MEMBER_BITOFFSET_Test_S3_o_ 0x6E
#define _CHAN_MEMBER_BITSIZE_Test_S3_o_ 0x0A
#define _CHAN_MEMBER_BITOFFSET_Test_S3_p_ 0x6D
```

```
#define _CHAN_MEMBER_BITSIZE_Test_S3_p_ 0x01
#define _CHAN_MEMBER_BITOFFSET_Test_S3_q_ 0x6C
#define _CHAN_MEMBER_BITSIZE_Test_S3_q_ 0x01
#define _CHAN_MEMBER_BITOFFSET_Test_S3_r_ 0x67
#define _CHAN_MEMBER_BITSIZE_Test_S3_r_ 0x01
#define _CHAN_MEMBER_BYTEOFFSET_Test_S3_s1_2_ 0x04
```

Enumeration information is exported using the settings mnemonic ENUM_LITERAL and with a <Misc> portion that is the enum name and literal concatenated. For example:

```
enum timebase_t
{
   tcr1_base,
   tcr2_base
};
```

Yields:

```
// defines for type enum timebase_t
// values of the literals of an enum type
// value = _CHAN_ENUM_LITERAL_FPM_timebase_t_tcr1_base_
#define _CHAN_ENUM_LITERAL_FPM_timebase_t_tcr1_base_ 0x00
#define _CHAN_ENUM_LITERAL_FPM_timebase_t_tcr2_base_ 0x01
```

7.2.9 Global Mnemonic

The GlobalMnemonic is text that is prepended to #ifdef's and #define's in the auto header file. It is intended to be used to avoid clashes with similar constructs in other files. The default GlobalMnemonic is an the underscore character, '_'.

7.2.10 Settings, Register Fields, and Mnemonic

Setting	Register/ Field	Mnemonic	Units
Entry Table Base Address	ETPUECR. ETB	ENTRY_TABLE_BASE_ADDR	Byte Address

Setting	Register/ Field	Mnemonic	Units
Entry Table Type (standard/ alternate)	CXCR.ETCS	ENTRY_TABLE_TYPE	0==Std 1==Alt
Entry Table Pin Direction (input/ Output)	CXCR.ETPD	ENTRY_TABLE_PIN_DIR	0=Input 1=Output
Function Number	CXCR.CFS	FUNCTION_NUM	None
8-bit Channel Variable Offset	CXCR.CPBA	CPBA8 CPBA_BOOLBITOFFSET	Bytes Bits
16-bit Channel Variable Offset	CXCR.CPBA	CPBA16	Bytes
24-bit Channel Variable Offset	CXCR.CPBA	CPBA24	Bytes
32-bit Channel Variable Offset	CXCR.CPBA	CPBA32	Bytes
Array Channel Variable Offset & Length/Stride	CXCR.CPBA	CPBA_ARRAY CPBA_TYPE_ARRAY DIM_<N>_LENGTH DIM_<N>_STRIDE	Bytes <type> Count Bytes
Struct Channel Variable Offset	CXCR.CPBA	CPBA_STRUCT	Bytes
Union Channel	CXCR.CPBA	CPBA_UNION	Bytes

Setting	Register/ Field	Mnemonic	Units
Variable Offset			
Struct/Union Member Offsets		CHAN_MEMBER_TYPE CHAN_MEMBER_BYTEOFFSET CHAN_MEMEBR_BITOFFSET CHAN_MEMBER_BITSIZE CHAN_MEMBER_<name>_DIM_<>	<type> Bytes Bits Bits
Tag Type Data		CHAN_TAG_TYPE_SIZE CHAN_TAG_TYPE_RAW_SIZE CHAN_TAG_TYPE_ALIGNMENT	Bytes
Enum literal values		CHAN_ENUM_LITERAL	
Variable Type		CPBA_TYPE	<type>
Channel Frame Size	CXCR.CPBA	FRAME_SIZE	Bytes
Initialized Frame Constants	RAM	FRAME_CONTENTS	Bytes
8-bit Channel Variable Offset	ECRX.ERBA	ERBA8 ERBA_BOOLBITOFFSET	Bytes Bits
16-bit Channel Variable Offset	ECRX.ERBA	ERBA16	Bytes

Setting	Register/ Field	Mnemonic	Units
24-bit Channel Variable Offset	ECRX.ERBA	ERBA24	Bytes
32-bit Channel Variable Offset	ECRX.ERBA	ERBA32	Bytes
Array Channel Variable Offset & Length/Stride	ECRX.ERBA	ERBA_ARRAY ERBA_TYPE_ARRAY DIM_<N>_LENGTH DIM_<N>_STRIDE	Bytes <type> Count Bytes
Struct Channel Variable Offset	ECRX.ERBA	ERBA_STRUCT	Bytes
Union Channel Variable Offset	ECRX.ERBA	ERBA_UNION	Bytes
Struct/Union Member Offsets		ENG_MEMBER_TYPE ENG_MEMBER_BYTEOFFSET ENG_MEMEBR_BITOFFSET ENG_MEMBER_BITSIZE ENG_MEMBER_<name>_DIM_<>	<type> Bytes Bits Bits
Tag Type Data		ENG_TAG_TYPE_SIZE ENG_TAG_TYPE_RAW_SIZE ENG_TAG_TYPE_ALIGNMENT	Bytes
Enum literal		ENG_ENUM_LITERAL	

Setting	Register/ Field	Mnemonic	Units
values			
Variable Type		ERBA_TYPE	<type>
8-bit Global Variable Offset	RAM	GLOB_VAR8 GLOB_VAR8_BOOL_BIT_OFFSET	Bytes Bits
16-bit Global Variable Offset	RAM	GLOB_VAR16	Bytes
24-bit Global Variable Offset	RAM	GLOB_VAR24	Bytes
32-bit Global Variable Offset	RAM	GLOB_VAR32	Bytes
Array Channel Variable Offset & Length/Stride	RAM	GLOB_ARRAY GLOB_TYPE_ARRAY DIM_<N>_LENGTH DIM_<N>_STRIDE	Bytes <type> Count Bytes
Struct Channel Variable Offset	RAM	GLOB_STRUCT	Bytes
Union Channel Variable Offset	RAM	GLOB_UNION	Bytes
Struct/Union Member Offsets		GLOB_MEMBER_TYPE GLOB_MEMBER_BYTEOFFSET GLOB_MEMEBR_BITOFFSET	<type> Bytes Bits

Setting	Register/ Field	Mnemonic	Units
		GLOB_MEMBER_BITSIZE GLOB_MEMBER_<name>_DIM_<>	Bits
Tag Type Data		GLOB_TAG_TYPE_SIZE GLOB_TAG_TYPE_RAW_SIZE GLOB_TAG_TYPE_ALIGNMENT	Bytes
Enum literal values		GLOB_ENUM_LITERAL	
Variable Type		GLOB_VAR_TYPE	<type>
Global Variable Size	RAM	GLOBAL_VAR_SIZE	Bytes
Global Scratchpad Size (when global scratchpad programming model is enabled)	RAM	GLOBAL_SCRATCHPAD_SIZE	Bytes
Global Data Size	RAM	GLOBAL_DATA_SIZE	Bytes
Global Data Init Address	RAM	GLOBAL_INIT_DATA_ADDR	Bytes
Maximum Stack Size	RAM	STACK_SIZE	Bytes
Engine Variable Size	RAM	ENGINE_VAR_SIZE	Bytes

Setting	Register/ Field	Mnemonic	Units
Engine Scratchpad Size (when engine scratchpad programming model is used)	RAM	ENGINE_SCRATCHPAD_SIZE	Bytes
Engine Data Size	RAM	ENGINE_DATA_SIZE	Bytes
Code Image (‘C’-array)	SCM	SCM_CODE_MEM_ARRAY	None
MISC Value **Error! Bookmark not defined.**	MISCCMPR	MISC_VALUE	None
Fill Value	N/A	FILL_VALUE	None
Jump Table Indices	N/A	<TableName>	
Constant Lookup Table Base Address	SCM Address	CONSTANT_LOOKUP_ADDR_<Name>	Bytes
HSR Number	CXHSRR.HSR	N/A	
Function Mode[6] Bits	CXSCR.FM	N/A	

7.2.11 Include Race Keepout

In order to avoid the possibility of infinite recursive inclusion of header file, the following text precedes all other #defines.

```
#ifndef <GlobalMnemonic>_<FileName>_H__
#define <GlobalMnemonic>_<FileName>_H__
```

For the same reason, the following is found at the end of the file.

```
#endif // <GlobalMnemonic>_<FileName>_H__
```

7.2.12 Freescale API compatibility

NXP provides a set of API for interfacing to eTPU code. The auto-generated file is included into the source code for that API.

7.2.13 ASH WARE Simulator Compatibility

All auto-header generated text is compatible with the eTPU simulator such that the header file can be included into the simulator and the resulting #defines can be used as arguments in the script command line. Additionally, ETEC provides supporting macros that when combined with the auto-defines file, make simulator script writing a simpler task. The simulator macro library can be found in the etec_sim_autodefs.h file found under the Sim directory in the ETEC installation.

7.2.14 Support for Additional Languages

Currently the auto header capability is targeted at “C”. Please contact the factory should you require support for additional languages such as Fortran, ADA, Java, etc.

7.2.15 SCM ARRAY

The SCM_ARRAY is written to its own file <output file name>_scm.c. By default it is output as an initialized array of 32-bit unsigned integers. The linker –data8 option causes it to be output as an array of unsigned 8-bit data.

7.2.16 PWM Example

The following is generated from the PWM

```
// This file is auto-generated by ETEC.
// It contains information for host-CPU side driver code

#ifndef  _PWM_ETEC_PWM_H__
#define  _PWM_ETEC_PWM_H__

// Register ECR, field ETB, byte address, Each Engine
// ECR.ETB = (__ENTRY_TABLE_BASE_ADDR)>>10
#define  __ENTRY_TABLE_BASE_ADDR  0x2800

// Register CXCR, Field ETCS, channels using PWM
// CXCR.ETCS = __PWM_ENTRY_TABLE_TYPE
#define  __PWM_ENTRY_TABLE_TYPE  1

...(etc)

#endif // __PWM_ETEC_PWM_H__
```

8
Initialized Data Files

The initialized data files contains data structures that, in conjunction with the memcpy() function, can be used to initialize your global and channel-frame memory.

Note that there may be “holes” in the initialized data. Holes are areas where un-initialized variables are located, or areas (due to the funny 24-bit nature of the eTPU) where there are simply no variables located. Holes get initialized to zero. Holes may be interspersed between valid initialized data.

The data itself is packaged in macros output into the <output file name>_idata.h file. These macros take the form of MacroName(address_or_offset , data_value). In the <output file name>_idata.c file the macros are used to create initialized arrays, ready for use by host-side eTPU initialization code.

By default the data is packaged as 32-bit unsigned integers. The linker option –data8 can be used to output the data as unsigned 8-bit instead.

8.1 Initialized Global Memory

The global memory data structure has the following form:

```
unsigned int <GlobalMnemonic>global_mem_init[] =
{
    0x00A02433, …,
};
```

The start address is the DATA RAM base plus the offset found in the auto-defines file. The actual text in the _idata.c file is different because the array initialization is done using the macros from the matching _idata.h, as follows:

```
// Global Memory Initialization Data Array
unsigned int _global_mem_init[] =
{
#undef __GLOBAL_MEM_INIT32
#define __GLOBAL_MEM_INIT32( addr , val ) val,
#include "DeclTest_B_idata.h"
#undef __GLOBAL_MEM_INIT32
};
```

8.2 Initialized Channel Memory

Each channel (and sometimes groups of channels) has a private copy of its own memory. It is this private memory that allows (say) a channel running the PWM function to have its own unique Period and Pulse Width, even when many channels may be running the same PWM function. The data structure has the following form, where name is the name of the class (in ETEC mode) or the eTPU Function (in Legacy Mode.)

```
unsigned int <GlobalMnemonic><Name>_frame_init[] =
{
     0x0022A317, …,
};
```

As with the initialized global data, the actual arrays in the _idata.c file are built up from macros in the matching _idata.h file (eTPU Function “Test”):

```
// Test Channel Frame Initialization Data Array
unsigned int _Test_frame_init[] =
{
#undef __Test_CHAN_FRAME_INIT32
#define __Test_CHAN_FRAME_INIT32( addr , val ) val,
#include "DeclTest_B_idata.h"
#undef __Test_CHAN_FRAME_INIT32
};
```

8.3 Using the Initialized Data Macros in the Simulator

The initialized data macros in the _idata.h file can be used in the eTPU Stand-Alone simulator to simulate the host-side initialization of global data and channel frames. An example is show below:

```
// load the global initialized data
#undef __GLOBAL_MEM_INIT32
#define __GLOBAL_MEM_INIT32(address, value) \
           *((ETPU_DATA_SPACE U32 *) address) = value;
#include "DeclTest_B_idata.h"
#undef __GLOBAL_MEM_INIT32

// load the "Test" channel frame for one channel
// in this example the channel frame base
// is hardcoded to 0x100
#undef __Test_CHAN_FRAME_INIT32
#define __Test_CHAN_FRAME_INIT32(offset, value)  \
        * ((ETPU_DATA_SPACE U32 *)               \
        0x100+offset) = value;
#include "DeclTest_B_idata.h"
#undef __Test_CHAN_FRAME_INIT32
```

9

Command Line Options

This section covers the command line options for both the compiler and the preprocessor.

9.1 Compiler Command Line Options

The compiler is called ETEC_cc.exe, and it has the following format:

```
ETEC_cc.exe <options> <source file name>
```

where options can be any of the following:

Setting	Option	Default	Example
Display Help This option overrides all others and when it exists no compilation is actually done.	-h, /? or -?	Off	-h
Open Manual Opens the electronic version of this Assembler Reference	-man	Off	-man

Setting	Option	Default	Example
Manual.			
Open a Specific Manual Opens an electronic version of the specified manual.	-man=<MANUAL> where MANUAL is one of the following: TOOLKIT: Toolkit User Manual. COMP: Compiler Reference Manual LINK: Linker Reference Manual. ASMFS: eTPU Assembler Reference Manual - NXP Syntax. ASMAW: eTPU Assembler Reference Manual - ASH WARE Syntax. ETPUSIM: Stand-Alone eTpu Simulator Reference Manual. MTDT: Common reference manual covering all simulator/ debugger products EXCEPT the eTPU Stand-Alone simulator. LICENSE: License reference manual	Off	-man=ETPUCIM
Display Version	-version	Off	-version

Setting	Option	Default	Example
Displays the tool name and version number and exits with a non-zero exit code without compilation.			
Display Licensing Info Outputs the licensing information for this tool.	-license	Off	-license
Target Selection Select the destination processor for the compilation.	-target=<TARGET> where TARGET can be: - ETPU1 : compile for the baseline eTPU processor. - ETPU2 : compile for the eTPU2 processor version. (TBD)	ETPU1	-target=ETPU2
Console Message Verbosity Control the verbosity of the compiler message output.	-verb=<N> where N can be in the range of 0 (no console output) to 9 (verbose message output).	5	-verb=9
Console Message Suppression Suppress console messages by their type/ class. Multiple types can be specified with multiple –verbSuppress options.	-verbSuppress=<TYPE> where TYPE can be: - BANNER : the ETEC version & copyright banner. - SUMMARY : the success/failure warning/error count	Off	-verbSuppress=SUMMARY

Setting	Option	Default	Example
	summary line - WARNING : all warning messages - ERROR : all error messages (does not affect the tool exit code)		
Console Message Style Controls the style of the error/warning output messages, primarily for integration with IDEs	-msgStyle=<STYLE> where STYLE can be: - ETEC : default ETEC message style. - GNU : output messages in GNU-style. This allows the default error parsers of tools such as Eclipse to parse ETEC output and allow users to click on an error message and go to the offending source line. - DIAB : output messages in the style used by Diab (WindRiver) compilers. - MSDV : output in Microsoft Developer Studio format so that when using the DevStudio IDE errors/ warnings can be clicked on to bring focus to the problem	ETEC	-msgStyle=MSDV

Setting	Option	Default	Example
	source code line.		
Console Message Path Style Controls how the path and filename are displayed on any warning/error messages that contain filename information.	-msgPath=<STYLE> where STYLE can be: - ASIS : output the filename as it is input on the command line (or found via #include or search). - ABS : output the filename with its full absolute path.	ASIS	-msgPath=ABS
Console Message Limit Controls the number of messages output (warning or error), before output goes silent. Note that if the first error occurs after the message limit is exceeded, that first error is still output.	-msgLimit=<CNT>	50	-msgLimit=20
Source File Search Paths Specifies any directories, after the current one, to be searched for included files. Multiple paths can be specified and they are searched in the order of their appearance in the command line.	-I=<PATH> where PATH is a text string representing either a relative or absolute directory path. The entire option must be in quotes if the path contains spaces.	None	-I=..\Include

Setting	Option	Default	Example
Source File Search Path Mode Specifies any directories, after the current	-IMode=<MODE> where MODE can be: - SOURCEREL : search paths specified with -I are relative to the source file being compiled. - CWDREL : search paths specified with -I are relative to the current working directory.	SOURCEREL	-IMode=CWDREL
Macro Definition Supplies a macro definition to the pre-processing stage of compilation.	-d=<MACRO> where if MACRO is an identifier than it is pre-defined to a value of 1, otherwise it can be of the form macro=definition, where macro gets the value specified in ‘definition’.	None	-d=DBG_BUILD
Output File Overrides the default behavior of generating an object file with the same base name as the source file, but with the .eao extension.	-out=<FILENAME> where FILENAME is written with the compilation output. If FILENAME does not have an extension, .eao is added automatically. The entire option must be in quotes if FILENAME contains spaces.	None	-out=file.obj
Static Data Packing	-packstatic=<OPTION>	PACKTIG	-

Setting	Option	Default	Example
Allow control of the style for packing/ allocating static channel frame data. It does not apply to global variables, which are packed as if FASTACCESS were applied to them.	where OPTION can be: - PACKTIGHT : packs data as tight as possible; locations of sequentially declared variables are not necessarily sequential. Additionally, accesses to some data types may not be coherent with regards to neighboring data, when this setting is used. - FASTACCESS : packs data so as to provide the fastest access possible by allocating space in optimal spots. Uses more memory but increases code speed and removes coherency conflicts.	HT	packstatic=FAST ACCESS
Array Data Packing Controls how data in arrays is packed for arrays of 8 and 16-bit types. This setting also affects the corresponding pointer type arithmetic (i.e. pointers increment/decrement by the same amount as the corresponding array stride size)	-packarray=<OPTION> where OPTION can be: - PACKTIGHT : for 8 and 16-bit types, the array stride size is the same as the base size (1 and 2 bytes respectively). - FASTACCESS : the stride size for 8 or 16 bit type arrays is always 4 bytes,	PACKTIG HT	- packarray=FAST ACCESS

Setting	Option	Default	Example
	resulting in optimal load/store performance but potentially increased memory usage.		
Struct Data Packing Control how members are placed in a structure.	-packstruct=<OPTION> where OPTION can be: - PACKTIGHT : packs members as tight as possible; offsets of sequentially declared members are not necessarily sequential. Additionally, accesses to some members may not be coherent with regards to neighboring data, when this setting is used. - FASTACCESS : packs members so as to provide the fastest access possible by locating data in optimal spots. Uses more memory but increases code speed and removes coherency conflicts. - LEGACY : packs members similar to PACKTIGHT, but with slight differences as it attempts to	PACKTIGHT	-packstruct=FASTACCESS

Setting	Option	Default	Example
	exactly mimic legacy tools structure packing algorithms.		
ANSI Mode Enforces ANSI behavior with structure & array packing. Where ANSI-compliant code is not generated a warning is issued. Care should be taken using this is it can reduce code efficiency and increase memory usage.	-ansi	Off	-ansi
Preprocessor Only This option stops compilation after the C preprocessing stage. If an output file has been specified via –out, the results go to that, otherwise the preprocessed source is output on stdout.	-ppOnly	Off	-ppOnly
Signed Char When specified, “char” variables are treated as signed. The ETEC default is to treat “char” as unsigned.	-signedchar	Off	-signedchar

Setting	Option	Default	Example
Unsigned Char When specified, "char" variables are treated as unsigned. This is the ETEC default so this option is superfluous.	-unsignedchar	On	-unsignedchar
Use Global Scratchpad Model When specified, code is compiled using the scratchpad programming model rather than the stack-based programming model. The scratchpad is located in global memory, and thus care must be taken to avoid conflicts on dual-eTPU systems.	-globalScratchpad	Off	-globalScratchpad
Use Engine Scratchpad Model When specified, code is compiled using the scratchpad programming model rather than the stack-based programming model. The scratchpad is located in engine-relative address space. This option is only available on the	-engineScratchpad	Off	-engineScratchpad

Setting	Option	Default	Example
eTPU2.			
Error on Warning Turn any warning into a compilation error. Note: this is the same option as -warnError which has been deprecated.	-strict	Off	-strict
Warning Disable Disable a specific compilation warning via its numerical identifier.	-warnDis=<WARNID>	Off (all warnings enabled)	-warnDis=343

Note that the source file name is not constrained to be the last command line argument, but that is the standard practice. Also note that command line options are not case-sensitive, however, there can be no spaces between the option, the '=' (if any) and the option data. Option data that contains spaces must be enclosed in quotes (the whole option).

9.2 C Preprocessor Command Line Options

The C Preprocessor executable is called ETEC_cpp.exe, and it has the following format:

```
ETEC_cpp.exe <options> <source file>
```

Where available options are listed & described below. Note that the source file name is not constrained to follow the list of options. Also note that command line options are not case-sensitive, however, there can be no spaces between the option, the '=' (if any) and the option data. Option data that contains spaces must be enclosed in quotes (the whole option).

Setting	Option	Default	Example
Display Help This option overrides all others and when it exists no compilation is actually done.	-h or /?	Off	-h
Macro Definition Supplies a macro definition for use during preprocessing.	-d=<MACRO> where if MACRO is an identifier than it is pre-defined to a value of 1, otherwise it can be of the form macro=definition, where macro gets the value specified in 'definition'.	None	-d= DBG_BUILD
Source File Search Paths Specifies any directories, after the current one, to be searched for included files. Multiple paths can be specified and they are searched in the order of their appearance in the command line.	-I=<PATH> where PATH is a text string representing either a relative or absolute directory path. The entire option must be in quotes if the path contains spaces.	None	-I=..\Include
Mode (Compatibility) Tells the C preprocessor to run in the specified mode.	-mode=<MODE> where MODE can be: - ETPUC : handle existing code better.	Off	-mode=ETPUC
Preprocessor Output File Sends the preprocessed	-out=<FILENAME> where FILENAME is	Off	-out=etpu_pwm.i

Setting	Option	Default	Example
source to the specified file, rather than placing it on stdout per the default.	written with the source file preprocessing result.		
Console Message Verbosity Control the verbosity of the compiler message output.	-verb=<N> where N can be in the range of 0 (no console output) to 9 (verbose message output).	5	-verb=9
Console Message Suppression Suppress console messages by their type/ class. Multiple types can be specified with multiple –verbSuppress options.	-verbSuppress=<TYPE> where TYPE can be: - BANNER : the ETEC version & copyright banner. - SUMMARY : the success/failure warning/error count summary line - WARNING : all warning messages - ERROR : all error messages (does not affect the tool exit code)	Off	-verbSuppress= SUMMARY
Console Message Style Controls the style of the error/warning output messages, primarily for integration with IDEs	-msgStyle=<STYLE> where STYLE can be: - ETEC : default ETEC message style. - GNU : output messages in GNU-	ETEC	-msgStyle= MSDV

Setting	Option	Default	Example
	style. This allows the default error parsers of tools such as Eclipse to parse ETEC output and allow users to click on an error message and go to the offending source line. - DIAB : output messages in the style used by Diab (WindRiver) compilers. - MSDV : output in Microsoft Developer Studio format so that when using the DevStudio IDE errors/ warnings can be clicked on to bring focus to the problem source code line.		
Console Message Path Style Controls how the path and filename are displayed on any warning/ error messages that contain filename information.	-msgPath=<STYLE> where STYLE can be: - ASIS : output the filename as it is input on the command line (or found via #include or search). - ABS : output the filename with its full absolute path.	ASIS	-msgPath=ABS

Setting	Option	Default	Example
Console Message Limit Controls the number of messages output (warning or error), before output goes silent. Note that if the first error occurs after the message limit is exceeded, that first error is still output.	-msgLimit=<CNT>	50	-msgLimit=20
Display Version Displays the tool name and version number and exits with a non-zero exit code without compilation.	-version	Off	-version
Display Licensing Info Outputs the licensing information for this tool.	-license	Off	-license
Error on Warning Turn any warning into a preprocessing error.	-warnError	Off	-warnError
Warning Disable Disable a specific preprocessing warning via its numerical identifier.	-warnDis=<WARNID>	Off (all warnings enabled)	-warnDis=343

9.3 Console Message Verbosity (-Verb)

A value of zero causes all error and warning messages to be suppressed. The only feedback from the tool suite is the exit code which is zero on success and non-zero on error.

A value of one causes only the number of errors and warnings to be printed to the screen. The actual error and warning messages are suppressed.

```
CC   Success (3 Warnings) EntryTable.c -> EntryTable.eao
Asm  Success EntryTable.sta -> EntryTable.eao
Link Success  EntryTable,Shift,... -> EntryTable.gxs
```

A value of three:

[NOTE: the console utility will buffer up the first line, “Assembling file Shift.sta” …, and only prints it out on detection of one or more errors.]

```
CC   Success EntryTable.c -> EntryTable.eao
     Assembling file Shift.sta ...
     Warning: blah blah blah
     Warning: blah blah blah
     Warning: blah blah blah
Asm  Success (3 warnings)  Shift.sta -> Shift.eao
     Linking file Shift.eao ...
     Linking file Pwm.eao ...
     Linking file Test2.eao
     Warning: blah blah blah
     Warning: blah blah blah
Link Success  EntryTable,Shift,... -> EntryTable.gxs
```

A value of five, which is the default.

```
Version …asdffasf
     Assembling file Shift.sta ...
     Optons …
     Build stats …
     Success! 0 errors, 13 warnings.
```

A value of greater than five prints out more information in a way that is specific to each tool in the suite.

9.4 Version (-Version)

This command line option displays the tool name and version number and exits with a non-zero exit code without doing anything other than generating this message (no compile, no link, etc.) A non-zero (failing) exit code is returned in case the user has accidentally injected this command line argument into a make. The output is guaranteed to appear as follows so that a user can develop a parsing tool to determine the version of the tool being used a particular build.

```
<ToolName> Version <MajorRevNum>.<MinorRevNum> Build <BuildLetter>
```

Where ToolName is the name of the tool being used and is either "ETEC Compiler", "ETEC Assembler" or "ETEC Linker." MajorRevNum is the tool's major revision number. MinorRevNum is the tools minor revision number, and Build Letter is the build number of the tool. The following is an example using the ETEC Linker.

```
        C:\Mtdt\TestsHigh\ETEC_linker.exe –Version
```

The following output is generated using an early prototype linker.

```
        ETEC Linker Version 0.27 Build C
```

10 Limitations

Generally, the latest support details can be found at http://www.ashware.com. The sections below do outline some limitations that are expected to never change.

10.1 Restrictions to the ISO/IEC 9899 C Definition

No floating point (float or double types) support.

The ETEC system does not provide any portions of the C standard library.

11 Supported Features

The following 'C' language features are supported by the ETEC compiler.

11.1 General C Language Support

The current ETEC version has some limitations. The list below details the portions of the C language that are as yet unsupported.

- Function pointers
- Structure initializers
- Designators
- Variable-length arrays
- _Accum type not supported; subset of _Fract capability supported

11.2 eTPU Programming Model Support

Fully supported.

11.3 Compatibility Mode Support

This section refers to constructs and syntax specific to existing code.

11.3.1 Entry Table Support

The if-else block entry table model is fully supported.

11.3.2 #pragma support

Items in [] are optional. Only one of the items in a { } is allowed.

#pragma ETPU_function

Syntax:

```
#pragma ETPU_function <function name>
                      [, {standard | alternate}]
                      [, {etpd_input | etpd_output}]
                      [@ <function number>];
```

<function name> must match and precede a function in the source code of the same name, with a void return type and whose parameters represent the eTPU function's channel variables.

The standard / alternate setting controls the entry table type for the function (standard is default).

The entry table pin direction auto-defines macro generation is controlled by the etpd_input / etpd_output item. If not specified, nothing is generated into the auto-defines file (default of input).

<function number> is processed and passed to the linker. Function numbers are automatically assigned at link time if a static number was not specified.

It is assumed the function called out has an appropriate format of if/else blocks to defined the entry table, and compilation will fail if not, or if they do not match the standard or alternate setting.

No other legacy #pragma options are supported at this time.

12

Appendix A : Pragma Support

This section covers the #pragmas supported by the ETEC compiler. Note that these are generally also supported by the ETEC assembler. There are two classes of #pragmas - one class are "code" pragmas. The code pragmas affect how code is generated and optimized AND their location within the code is important. The second class is everything else. Currently, the following are the supported code pragmas:

- atomic_begin
- atomic_end
- optimization_boundary_all
- optimization_disable_start
- optimization_disable_end
- wctl_loop_iterations

The code pragmas syntactically work like C statements, and thus they must be placed within the source code like a C statement. The examples below show an incorrect placement and a valid code pragma placement.

```
if (...)
{
}
#pragma optimization_boundary_all // will fail
```

```
else
{
}
```

While the below would work:

```
if (...)
{
}
else
{
#pragma optimization_boundary_all // ok
...
}
```

12.1 Verify Version

A #pragma to verify that the proper version of the ETEC Compiler is being used to generate a particular piece of source code is available.

```
#pragma verify_version <comparator>, “<version string>”,
“<error message>”
```

When such a #pragma is processed by the compiler, a comparison is performed using the specified <comparator> operation, of the ETEC Compiler’s version and the specified “<version string>”. The supported comparators are:

```
GE – greater-than-equal
GT – greater-than
EQ – equal
LE – less-than-equal
LT – less-than
```

The specified version string must have the format of “<major version number>.<minor version number (2 digits)><build letter (letter A-Z)>”. The last token of the #pragma verify_version is a user-supplied error message that will be output should the comparison fail.

For example, if the compiler were to encounter the following in the source code

```
#pragma verify_version GE, "1.20C", "this build requires
ETEC version 1.20C or newer"
```

The ETEC Compiler will perform the test <ETEC Compiler version> >= “1.20C”, and if the result is false an error occurs and the supplied message is output as part of the error. With this particular example, below are some failing & passing cases that explain how the comparison is done

```
        // (equal to specified “1.20C”)
        ETEC Compiler version = 1.20C      => true

        // (major version is less than that specified)
        ETEC Compiler version = 0.50.G     => false

        // (minor version 21 greater than that specified)
        ETEC Compiler version = 1.21A      => true

        // (build letter greater than that specified)
        ETEC Compiler version = 1.20E      => true
```

12.2 Disabling Optimization in Chunks of Code

If it is desired to disable optimization on a section of code, the pragmas

```
        #pragma optimization_disable_start
```

and

```
        #pragma optimization_disable_end
```

can be used to do so. All optimizations are disabled within the specified region, so this feature should be used with care.

12.3 Disabling Optimizations by Type

The ETEC optimizer operates by applying a series of optimizations to the code, thereby reducing code size, improving worst case thread length, reducing the number of RAM accesses, etc. Although these optimizations are generally disabled en-masse from the command line using -opt-, it is also possible (but hopefully never) required to individually disable specific optimizations within a source code file using the following option.

```
        #pragma disable_optimization <Num>
```

This disables optimization number, <num>, in entire translation unit(s) in which the source code or header file is found.

The optimization numbers are not documented and must be obtained directly from ASH WARE. Note that the purpose of disabling specific optimizations is to work-around optimizer bugs in conjunction with ASH WARE support personnel.

12.4 Atomicity Control

An atomic region can be specified by the enclosing pragmas

```
#pragma atomic_begin
// code to be atomic
// ...
#pragma atomic_end
```

The contents of an atomic region must compile into a single opcode or an error results. This atomic opcode is guaranteed to be kept together throughout the optimization process.

12.5 Optimization Boundary (Synchronization) Control

The pragma

```
#pragma optimization_boundary_all
```

prevents any opcodes or sub-instructions from moving across the #pragma point in the source code. Generally this should not be used as it will result in degraded performance, but if a case arises wherein optimization produces unwanted behavior, it can be a useful construct.

12.6 Thread Length Verification (WCTL)

The verify_wctl pragma are used for the following:

- No thread referenced from a Class or eTPU Function (including both member threads and global threads) exceed a specified number of steps or RAM accesses.
- A specific thread does not exceed a specified number of steps or ram accesses.
- For classes with multiple entry tables, the worst-case thread of any entry table can be specified (currently only available in ETEC mode.)
- A global ‘C’ function or member ‘C’ function does not exceed a specified number of steps or ram accesses.

The syntax is as follows:

```
#pragma verify_wctl <eTPUFunction>            <MaxSteps>
steps <MaxRams> rams
```

```
#pragma verify_wctl <eTPUFunction>::<Thread>  <MaxSteps>
steps <MaxRams> rams

#pragma verify_wctl <Class>           <MaxSteps> steps
<MaxRams> rams
#pragma verify_wctl <Class>::<Thread>  <MaxSteps> steps
<MaxRams> rams
#pragma verify_wctl <Class>::<Table>   <MaxSteps> steps
<MaxRams> rams
#pragma verify_wctl <Class>::<CFunc>   <MaxSteps> steps
<MaxRams> rams

#pragma verify_wctl <GlobalCFunc>     <MaxSteps> steps
<MaxRams> rams
```

Note that global threads must be scoped with a class that references it. In other words, say there is a common global thread referenced from several different classes entry tables. The following syntax would be required where the class name is the name of one class that references the global thread.

```
#pragma verify_wctl <Class>::<GlobalThread>   <MaxSteps>
steps <MaxRams> rams
```

Some called functions (‘C’ functions or member functions) may have routes that return to the caller but also may end the thread. In such causes the verify_wctl acts on the longer of these two.

The WCTL analyses assumes that called functions are well-behaved in terms of call-stack hierarchy. For instance, if Func() calls FuncB() and FuncB() calls FuncC(), a return in FuncA() will go to the location in FuncB() where the call occurred. Additionally, a return within FuncB() will then return to Func() where that call occurred. In order for this to occur, the rar register must be handled correctly, which is guaranteed in ETEC compiled code, as long as inline assembly does not modify the RAR register. It is also guaranteed in assembly as long as RAR save-restore operations are employed in a function’s prologue and epilogue.

The WCTL calculations remain valid even when a thread ends in a called function.

The following are examples uses of verify_wctl:

```
// Verify WCTL of a global function
#pragma verify_wctl mc_sqrt 82 steps 0 rams

// Verify WCTL of a specific thread within a class
#pragma verify_wctl  UART::SendOneBit   25 steps 7 rams
```

```
// Verify WCTL of the longest thread within an entire class
#pragma verify_wctl  UART  30 steps 9 rams
```

12.7 Forcing the WCTL

In some cases a thread, eTPU function, or an eTPU class may not be able to be analyzed. This can occur when multiple loop are encountered or when the program flow is too convuluted for a static analyses. In these cases, the maximum WCTL can be forced using the following #pragma.

```
#pragma force_wctl <Name> <max_steps> steps <max_rams> rams
```

An example of this is the square root function in the standard library used in NXP set 4. This has two loops where the maximum number of times through each of the loops is inter-dependent, and this complicated loop limit relationship is well, not supported ETEC's worst case thread length analyses. The following #pragma is used to establish this limit

```
#pragma force_wctl  mc_sqrt  82 steps   0 rams
```

12.8 Excluding a thread from WCTL

A thread can be excluded from the WCTL calculation of a function. This is normally used for initialization or error handling threads that in normal operation would not contribute to the Worst Case Latency (WCL) calculation. The format is as follows:

```
#pragma exclude_wctl <eTPU Function>::<ExcludedInitThread>
```

For example the following excludes a UART's initialization thread from the worst case.

```
#pragma exclude_wctl UART::init
```

12.9 Loop Iteration Count

Loops in eTPU code are generally not a good programming practice because the eTPU is an event/response machine in which long threads (such as those caused by loops) can prevent the quick response time to meet many applications’ timing requirements.

However, loops are occasionally required, and are therefore supported by the optimizer.

But there is no way to analyze the worst case thread length for threads that contain loops, and therefore loops prevent analyses unless loop bounding iteration tags are added.

```
#pragma wctl_loop_iterations <max_loop_count>
<Some Loop>
```

12.10 Code Size Verification

The code size verification pragma, verify_code_size, allows the user to verify at build time that their code meets size requirements. Code size verification is done on a function scope basis. The pragma has the syntax options

```
#pragma verify_code_size  <Function>  <MaxSize>  bytes
#pragma verify_code_size  <Function>  <MaxSize>  words
#pragma verify_code_size  <Class>::<Function>  <MaxSize>  bytes
#pragma verify_code_size  <Class>::<Function>  <MaxSize>  words
```

The maximum allowable size for a given function can be specified in bytes or words (opcodes, 4 bytes each). If the actual size of the function exceeds MaxSize, the linker issues an error.

This pragma is available in both the Assembler and Compiler.

12.11 Memory Size (Usage) Verification

The memory usage verification pragma, verify_memory_size, allows the user to verify at build time that their memory usage meets size requirements. Memory usage is verified on a memory section basis. The pre-defined (default) memory sections are named & described below:

```
GLOBAL_VAR        - user-declared global variables

GLOBAL_SCRATCHPAD - local variables allocated
                    out of global memory (scratchpad)

GLOBAL_ALL        - all global memory usage

ENGINE_VAR        - user-declared variables
                    in engine-relative memory space
                    (eTPU2 only)

ENGINE_SCRATCHPAD - local variables allocated
                    out of engine-relative memory
                    (engine scratchpad, eTPU2 only)

ENGINE_ALL        - all engine-relative memory usage
```

```
                                (eTPU2 only)

        STACK               - maximum stack size
```

User-defined memory sections can also be verified. Currently only channel frames are supported – these are verified by specifying the appropriate eTPU class or function name.

The pragma has the following syntax options

```
#pragma verify_memory_size  <memory section>  <MaxSize>  bytes
#pragma verify_memory_size  <memory section>  <MaxSize>  words
#pragma verify_memory_size  <eTPU class/function>  <MaxSize>  bytes
#pragma verify_memory_size  <eTPU class/function>  <MaxSize>  words
```

The maximum allowable size for a given memory section (or channel frame) can be specified in bytes or words (4 bytes/word). If the actual size of the memory section exceeds MaxSize, the linker issues an error.

This pragma is available in both the Assembler and Compiler.

12.12 Same Channel Frame Base Address

When multiple channels use the same channel frame base address, there is no need to re-load channel variables when the channel is changed. In certain cases this can result in improvements in code speed and size. The following tells the compiler that the CPBA register value will be the same for all channel changes of within the specified function.

```
        #pragma same_channel_frame_base <etpu_function>
```

The etpu_function argument is the name of an eTPU function, C function, or eTPU class.

An example where this is useful is in the NXP set 1 SPI function, which controls multiple channels that all share the same channel frame base address. The SPI function can compile tighter when the ETEC tools know about this, which can be done by adding:

```
        #pragma same_channel_frame_base SPI
```

12.13 Auto-defines Export

Two #pragmas allow export of macros in the eTPU compilation environment, or user-defined text, into the auto-defines file. The export macro pragma has the following syntax:

```
#pragma export_autodef_macro "<output_macro_name>",
<output_macro_value>
```

The following lines in eTPU source:

```
#define TEST_INIT_HSR 7
#define TEST_STR "xyz"
#pragma export_autodef_macro "ETPU_TEST_INIT_HSR",
TEST_INIT_HSR
#pragma export_autodef_macro "TEST_STR", TEST_STR
```

Results in the following in the auto-defines file:

```
// exported autodef macros from user "#pragma
export_autodef_macro" commands
#define ETPU_TEST_INIT_HSR  7
#define TEST_STR  "xyz"
```

The standard header file "ETpu_Std.h" has a few "helper macros" available that can potentially make the eTPU source easier to read. Using the macros like:

```
#define TEST_ODD_PARITY_FM 1
#pragma export_autodef_macro EXPORT_AUTODEF_MACRO
(TEST_ODD_PARITY_FM)
#pragma export_autodef_macro EXPORT_AUTODEF_MACRO_PRE
("ETPU_", TEST_ODD_PARITY_FM)
```

Results in:

```
// exported autodef macros from user "#pragma
export_autodef_macro" commands
#define TEST_ODD_PARITY_FM  1
#define ETPU_TEST_ODD_PARITY_FM  1
```

There is also a pragma to export any user-defined text. Note that this text must be parseable by whatever compiler processes the auto-defines file when compiling host code, or it will break the compilation. The export text #pragma has this syntax:

#pragma export_autodef_text "<user_defined_text>"

The text must use C escape sequences when necessary, and can even include newlines for the output. For example:

```
#pragma export_autodef_text "#define EXPORT_AUTODEF_VAL 1"
#pragma export_autodef_text "#define
EXPORT_AUTODEF_STR \"abc\""
#pragma export_autodef_text "#define
EXPORT_AUTODEF_FUNC_MACRO(ARG1, ARG2) \\\n ARG1 = ARG2;"
```

Yields the following in the auto-defines file:

```
// exported autodef text from user "#pragma
export_autodef_text" commands
#define EXPORT_AUTODEF_VAL 1
#define EXPORT_AUTODEF_STR "abc"
#define EXPORT_AUTODEF_FUNC_MACRO(ARG1, ARG2) \
 ARG1 = ARG2;
```

12.14 Private Channel Frame Variables

When using the eTPU-C programming model, channel frame variables can be kept "private", that is, their information is not exported in the auto-defines file, by declaring them via the "static" technique and using the private channel frame pragma (#pragma private_static_channel_frame). The default behavior (no pragma) is to have all channel frame variables in an eTPU-C function be public. See the example below.

```
#pragma ETPU_function PWM, alternate;
#pragma private_static_channel_frame

void PWM(int24 Flag, // all parameters always exported to
auto-defines
         int24 Period,
         int24 ActiveTime,
         int24 Coherent_Period,
         int24 Coherent_ActiveTime )
{
     static int24 LastFrame; // not exported to auto-
defines because of pragma above
     static int24 NextEdge;

     // ...
```

A matching pragma to switch back to the default public model is:

```
#pragma public_static_channel_frame
```

12.15 Explicit Locating

Global symbols can be located at explicit addresses via #pragma.

```
#pragma locate_symbol  <Symbol Name>  <Address>
```

The pragma must occur in the source before and definition or declaration of the symbol. The address can be anywhere in SDM - thus explicitly located variables in eTPU code can be located outside the default low memory global address range of 0x0 - 0x400, and all accesses will be made using the architecture's indirect addressing mode. It is the main purpose of this capability to allow data (particularly large data buffers) to be placed at the end of memory, thereby leaving the low memory available for regular global variables or scratchpad. The address can be specified in octal, decimal or hexadecimal, and it must be a single constant (no expressions allowed). Some examples:

```
#pragma locate_symbol g_el_array 0x601
int24 g_el_array[16];
#pragma locate_symbol g_el_struct2 0x700
struct GS g_el_struct2;
```

or

```
// header file extern declaration
#pragma locate_symbol g1 0x400
extern int8 g1;
#pragma locate_symbol g2 0x406
extern int16 g2;
```

The address specified must have the proper alignment (address modulo 4) given the symbol type. Given the global scope, 8 bit variables have an alignment of 0 bytes, 16 bit variables have an alignment of 2 bytes, 24 bit align at an offset of 1 byte, and 32 bit variables of course align on the word boundary (0). Aggregate types will depend upon the exact contents and packing. A compilation error is thrown if the alignment is wrong.

Explicitly located symbols can overlay each other, but when detected, a warning is issued by the linker.

Regular global symbols/variables are treated as a block and will try to be located in the lowest memory address possible (ideally, starting at 0). Explicitly located symbols in low memory can push this off. Any global scratchpad is also treated as a contiguous block and will also try to be located in the lowest memory slot possible, after regular global variables are located. It is recommended that explicitly located globals not be placed into low memory as it can lead to holes, and possible cause regular globals and scratchpad to run out of memory.

The defines file has macros for the addresses for explicitly located symbols, but they are not counted as part of the global data size macros UNLESS they (some) are placed in low memory before regular global symbols. Note also that the macros for recommended channel frame and stack addresses do not account for explicitly located symbols, so take care. They are also listed in the .map file, but again not as part of the regular global data section. Last, explicitly located variables do not appear in the auto-struct output.

13

Appendix B : Data Packing Details

This appendix provide further detail on the non-default data packing modes (FASTACCESS), and more details on how ANSI mode affects packing. Again, note that these algorithms are not set in stone and code that uses them (and more specifically host code) should use the auto-defines data for working with data in the SDM.

13.1 Channel Frame FASTACCESS Mode

In FASTACCESS mode channel variables are allocated at address locations where they can be most efficiently accessed & operated on. Like TIGHT mode, larger objects are packed first. Note that 1-byte parameters can also occupy the low byte of the 3 LSByte area.

Given a set of channel frame variables:

```
int x, y;  // 24-bit vars
char c1, c2, c3, c4, c5, c6, c7;
short a, b, c; // 16-bit vars
struct SomeStruct somestruct;
    // sizeof(SomeStruct) == 8
```

The packing would look like:

SDM Channel Frame Address Offset	*MSByte*	*3 LSBytes*	
0	*c1*	*x*	
4	*c2*	*y*	
8	*somestruct*		
12			
16	*c3*	*unused*	*a*
20	*c4*	*unused*	*b*
24	*c5*	*unused*	*c*
28	*c6*	*unused*	*c7*

13.2 Structure FASTACCESS Mode

The FASTACCESS struct packing algorithm is again similar to FASTACCESS channel frame pack mode. A few examples are shown below:

```
struct TwoCharStruct
{
     char x; // offset 0
char y; // offset 3
}; // sizeof() == 4

struct Int16_8Struct
{
     int16 twobytes; // offset 2
     int8 onebyte; // offset 0
}; // sizeof() == 4

struct Int16_8_8Struct
```

```
{
    int16 twobytes; // offset 2
    int8 onebyte_1; // offset 0
int8 onebyte_2; // offset 4
}; // sizeof() == 5
```

Otherwise, see the FASTACCESS mode packing example in section 12.1.

13.3 Structure PACKTIGHT with ANSI Mode Enabled

The ANSI pack modes have similar rules to the non-ANSI versions, except that each struct member is considered in order for packing, and must have an offset greater than its predecessor. Note that member order can have significant impact on how tightly the data packs.

The set of channel frame variables:

```
int x, y;  // 24-bit vars
char c1, c2, c3, c4, c5, c6;
short a, b, c; // 16-bit vars
struct SomeStruct somestruct; // sizeof(SomeStruct) == 8
```

Would get packed like:

Struct Offset	*MSByte*	*3 LSBytes*		
0 (-1 actually since the base struct address is considered to start at x)	*unused*	*x*		
4 (3)	*unused*	*y*		
8 (7)	*c1*	*c2*	*c3*	*c4*
12 (11)	*c5*	*c6*	*a*	
16 (15)	*b*		*c*	

20 (19)	*somestruct*
24 (23)	

13.4 Structure FASTACCESS with ANSI Mode Enabled

This mode is similar to FASTACCESS packing, but with guaranteed ascending order of the member offsets. Note that member order can have significant impact on how tightly the data packs.

The set of channel frame variables:

```
int x, y;  // 24-bit vars
char c1, c2, c3, c4, c5, c6, c7;
short a, b, c; // 16-bit vars
struct SomeStruct somestruct; // sizeof(SomeStruct) == 8
```

Would get packed like:

Struct Offset	*MSByte*	*3 LSBytes*	
0 (-1 actually since the base struct address is considered to start at x)	*unused*	*x*	
4 (3)	*unused*	*y*	
8 (7)	*c1*	*unused*	*c2*
12 (11)	*c3*	*unused*	*c4*
16 (15)	*c5*	*unused*	*c6*
20 (19)	*c7*	*unused*	*a*
24 (23)	*unused*		*b*

28 (27)	*unused*	*c*
32 (31)	*somestruct*	
36 (35)		

13.5 Array FASTACCESS Mode

With array FASTACCESS mode the array stride size is always a multiple of 4. This also means that when using this mode, incrementing a pointer to char changes the address by 4 bytes rather than 1! Thus care must be taken when using this mode, however, it can generate significantly more efficient code when array access is required. Arrays of elements with a size of 1 byte are aligned on modulo 4 addresses. Elements of size 2 bytes are aligned at modulo 4 plus 2.

Some example declarations and the ensuing memory allocations are shown below:

```
char a[6]; // although only burns 6 bytes, sizeof() == 24
int b[3];
struct FiveByteStruct
{
char f1;
int f2;
char f3;
} c[2];
int24 x;
int8 y;
int16 z;
```

The resulting memory allocation map would look like:

SDM Channel Frame Address Offset	*MSByte*	*3 LSBytes*
0	*a[0]*	*b[0]*
4	*a[1]*	*b[1]*
8	*a[2]*	*b[2]*

12	*a[3]*	*x*	
16	*a[4]*	*unused*	*z*
20	*a[5]*	*unused*	*y*
24	*c[0].f1*	*c[0].f2*	
28	*c[0].f3*	*unused*	
32	*c[1].f1*	*c[1].f2*	
36	*c[1].f3*	*unused*	

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Appendix C : eTPU Annotated Object File Format

The eTPU Annotated Assembly format (.EAO) file format is an open format developed for the purpose of providing an object file format that a compiler or assembler outputs and that is an input to a linker or optimizer. This format is based on the existing and well documented GNU file format output by the GNU compiler when the –S (retain assembly file) is specified (COFF output only). A few distinguishing features of this format are listed below.

Text format that is human readable (no special visualization tool is required)

Not re-inventing the wheel, the existing GNU format is the baseline.

Where required, additional tags are invented (e.g. valid p_31_24 values on a dispatch operation)

All required debugging information is included such as originating source file names, line numbers, data, scoping, etc.

Format	*Example*	
.file “FileName”	`.file "main.c"`	*Name of the source code file from which all proceeding .line (line*

		number) tags refer. Relative pathing relative to CWD is employed.
.line <LineNum>	`.line 8`	*Source code line number from which proceeding opcodes are generated. Numbering goes from 1 to N.*
.dispatch	`.dispatch 0-3,7,9`	*Indicates valid p_31_24 dispatch values. Tag precedes the single dispatch instruction that it describes. A range is indicated using the <StartVal>-<EndVal>. Ranges are separated by commas*
.opten <opt #>		*Optimization Enable*
.optdis <opt #>		*Optimization Disable*
.region <type> "RegionName"		*<type> is the region type (coherency, ramsyncpoint, intsyncpoint, atomic, chanchange). RegionName should match at region start and end.*
.regionend "RegionName"		
.version <major>, <minor>, <build>		*Version of assembler or compiler that generated the .eao file.*
.producer { cc | asm }		

.def <name>		*Begins debugging information for a symbol* **name**. *The definition extends until the .endef directive is encountered.*
.def .bb		*Begins a new block.*
.def .bf		*Begins a function block.*
.def .eb		*Ends a block.*
.def .ef		*Ends a function block.*
.def .eos		*Ends a struct, union, or enum definition. The members of such are listed between the initial object .def/.endef and the .def . eos.*
.endef		*Ends a symbol definition begun with a .def directive.*
.global <symbolName >		*Makes symbol with symbolName visible for linking (extern).*
.scl <class #>		*Sets the storage-class value for a symbol. It can only be used inside a .def/.endef pair.*
.size <size #>		*Sets the storage size of a symbol. The numbers is in bytes, except if the symbol represents a bitfield, in which case it is in buts. It can only be used inside a .def/.endef pair.*

.tag <structName>		*Used to name and link to structure/union/enum definitions. It can only be used inside a .def/.endef pair.*
.type <type #>		*Provides the type attribute for a symbol. It can only be used inside a .def/.endef pair.*
.val <address>		*Sets the address, offset, or value of a symbol. It can only be used inside a .def/.endef pair.*
.etpufunction <functionName>		*Marks a symbol as a channel frame variable and associates with the proper eTPU function. It can only be used inside a .def/.endef pair.*
.defentry		*Used to begin the definition of a single entry in an entry table.*
.ettype { standard | alternate }		*Type of entry table*
.etpin{ input | output }		*Optional entry table pin direction conditional. Used by auto-header for setting the CxCr. ETPD — Entry Table Pin Direction*
.etpuclass <name>		*Optional name of the eTpuClass to which this entry is associated.*
.ettable <name>		*Optional name of the entry table. Note that in some applications a class may have multiple entry tables.*

.etlabel <name>		*Code label name that is the destination of this label. [If it is not mangled, the label must exist within the class or must be global]*
.index <N>		*Index of this entry, valid range is 0 to 31*
.val <Value>		*Value of this entry where the Preload Parameter (PP) and Match Enable (ME) have been encoded, but the Microcode Address has not.*
.etcfsr <Value>5		*Optional entry table channel function select value. This handles the (hopefully rare) case when the user specifies a specific CFSR value for a function*
.endentry		*Ends the entry definition.*
.init <val>,…, <val>		*For initializing global and channel variables*

Storage class values have the following meaning:

Value	***Storage Class***
0	*No storage class*
1	*Automatic variable*
2	*External symbol*
3	*Static (internal linkage)*
4	*Register variable*
5	*External definition*
6	*Label*
7	*Undefined label*
8	*Member of a structure*
9	*Function argument (parameter)*
10	*Structure tag*
11	*Member of a union*
12	*Union tag*
13	*Type definition*
14	*Uninitialized static*
15	*Enumeration tag*

16	*Member of an enumeration*
17	*Register parameter*
18	*Bit field*
19	*Tentative definition*
20	*Static .label symbol*
21	*External .label symbol*
100	*Beginning or end of a block*
101	*Beginning or end of a function*
102	*End of structure (or union, enumeration)*
103	*Filename*
104	*Used only by utility programs*

Type attributes have the following meaning:

Value	***Type Attribute***
0	*Void type*
1	*Signed character*
2	*Character*
3	*Short integer*

4	*Integer*
5	*Long integer*
6	*Floating point*
7	*Double word*
8	*Structure*
9	*Union*
10	*Enumeration*
11	*Long double precision*
12	*Unsigned character*
13	*Unsigned short integer*
14	*Unsigned integer*
15	*Unsigned long integer*

14.1 Code Labels

Code labels have the following form

```
.codelabel <name> .type <N> .codelabelend;
```

Where <name> is the mangled name of the code label, <N> is the code label type where a type of 0 indicates a natural label, and a type of 1 indicates a compiler contrived type. An example of a contrived type is the labels generated by an if-else “C” construct.

The following is an example of a code label that is generated by the assembler.

```
.codelabel _Add_AW613E_Main_; .type 0; .endcodelabel;
```

14.2 Entries

Each entry table entry must have the following form. The .index directive indicates which of the 32-entries for this table is being defined. All 32 entries must be defined.

```
.defentry; .ettype standard; .etpin input; .etpuclass Add;
.ettable AW6B2D_NAMELESS_ENTRY_TABLE; .etlabel DanglingElse; .index 0;
.val 0x4000; .line 70; .etcfsr 5; .endentry;
```

15

Appendix D : Error, Warning and Information Messages

The ETEC tool suite provides a lot of feedback with regards to compilation errors, warnings and informational messages. The tables below list the messages that can be issued by the tools.

15.1 Compiler Error Messages

Message Identifier	Explanation
001	Currently unsupported feature; planned to be supported in the future.
002	Factory error – should never occur, but if it does report error to the factory.
100	Invalid command line option encountered.
110	Could not open specified source file.

Message Identifier	Explanation
120	Overflow of the C preprocessor buffer (may be passing too many long –d options, or to many long –I paths).
121	The C Preprocessor could not be run (is installation correct?).
122	The C Preprocessor could not be run (is installation correct?).
123	Preprocessing error occurred; message will provide further details.
200	Syntax error.
210	Invalid declaration.
220	Multiple default labels found in a switch statement.
221	A break statement found outside any enclosing switch or iteration statement.
222	A continue statement found outside any enclosing iteration statement.
230	Invalid if-else statement found.
231	Invalid switch statement found.
232	Case expression invalid (note that case expressions must be constant expressions).
240	For loop test expression is invalid.
241	For loop initialization expression is invalid.

Message Identifier	Explanation
242	For loop iteration expression is invalid.
245	While loop expression is invalid (do-while included).
250	Invalid function scope.
251	Invalid function definition.
252	Scoping error (mismatch) detected.
260	Duplicate label found.
270	No return for non-void function.
271	Return type does not match the function definition return type.

15.2 Compiler Warning Messages

Message Identifier	Explanation
001	Currently unsupported feature (that can be ignored).
100	Empty source file sent through compiler – no tokens found.
101	A bad command line option found that can be ignored.
110	An unrecognized #pragma encountered.
111	An invalid optimization ID was specified with –optEn or –

Message Identifier	Explanation
	optDis; it is ignored.
120	C preprocessing warning message.
200	An identifier longer than 255 characters found and truncated to 255 significant characters.
210	Warn about non-ANSI/ISO compliant generated code (-ansi mode only)
300	An incomplete global array definition encountered; it is assumed to have only one element.
310	An inner scope identifier name is masking the same name from an outer scope.
320	An array string initializer is too large to fit in the array; it is truncated.
330	Multiple of the same type qualifiers detected.
340	No function return type is specified; defaulting to int return type.
350	A declared local variable encountered that is not ever used.
400	Signed and unsigned values are being compared and thus may yield unexpected results (comparison is unsigned).
401	Value to be assigned is not of the same type; an implicit conversion is done.
410	Shift by a negative constant is ignored.

Message Identifier	Explanation
411	Shift by a zero constant is ignored.
420	Constant conversion results in truncation.
421	Constant conversion to fact was saturated.
422	Constant truncated to fit in bitfield.