

EXTERNAL PRODUCT SPECIFICATION
FOR THE
MCS-51 OBJECT MODULE FORMAT

V5.0

APPROVED

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1 PREFACE

The document defines the internal format of the relocatable object files (Object Module Formats, OMF) for the 8051 family, produced by Intel's language translators and processed by other Intel software products. Appendix C defines the Absolute Object Module Format (AOMF) which is produced by the RL51 program (and the RASM, if the source program is absolute). The information in this document is normally not needed in order to use Intel software, but is provided for the person who needs to write programs to process these object files or to create files in the same formats. The design is heavily based on the previous OMFs for the 8080 and the 8086 [1] [2].

Chapter 2 covers some background material for those interested in the relevant 8051 architecture issues and the R&L requirements which led to the definition of the object file formats.

Terms which may have special meaning in the document are described in the glossary (Appendix B).

2 OVERVIEW OF 8051 ARCHITECTURE

The following discussion outlines those aspects of the 8051 architecture relevant to linking and locating - the memory model and the addressing modes.

The memory model of the 8051 family consists of three non-overlapping address spaces - the code space, the external data space and the on-chip RAM. Some sections of the on-chip RAM space serve functions in addition to being the usual random access byte storage. These include bit-addressable memory, and stack.

2.1 Code Space

The code space size is 64K bytes. The lower 4K are on-chip ROM and the top 60K resides in external memory components. The lower portion of the on-chip ROM contains a reset vector (at location 0) and 5 interrupt vectors (at locations 3, 0BH, 13H, 1BH and 23H).

The code space usually consists of all the procedure and constants of a program. It is assumed that all the code space (off-chip as well) consists of ROM. Consequently only read operations are available on data in the code space.

Four code addressing modes are provided:

- a. Direct Addressing - The second and third byte of the instruction form the full 16 bit address (used in jump and call instructions). Setup instruction (MOV DPTR, code_address).
- b. Block addressing - The instruction provides the 11 least-significant bits of the address. The block address is defined by the 5 most-significant bits of the incremented PC. Used in jump and call instructions.

- c. Relative Addressing - The instruction provide 8 bit relative offset. Used in conditional jumps in a range of +127/-128 of the incremented PC.
- d. Indirect Addressing - The address is composed of the DPTR or PC content, indexed by the 8 bit accumulator.

2.2 External Data Space

The External Data space size is 64K bytes. This space is completely external to the chip. Access is provided via move instructions which move bytes between the external data space and the accumulator.

Two external data addressing modes are provided:

- a. Indirect DPTR - the 16 bit DPTR is used to address any location in the external data space.
- b. Indirect Register - R0 or R1 are used to address a location within a 256 byte page defined by the content of the Port 2 register.

The pointing registers DPTR, R0 and R1 should be set up before the actual access is being made. The machine provide instructions for loading the DPTR with a constant (e.g. external data address) and incrementing it. It provides many instructions which load/manipulate the 8 bit pointers R0 and R1.

2.3 Internal Data Space

The on-chip RAM space consists of 128 bytes (up to 256 bytes for a few members of the family, e.g. 192 for the RUPI) of data memory and 128 bytes of memory mapped hardware registers. The on-chip RAM space is organized as follows:

	DIRECT ADDRESSING	INDIRECT ADDRESSING	
256	Hardware Registers	Future Additional RAM	
192		RUPI Additional RAM	
128	Free RAM		
48	Bit Space		
32	Register Bank 3		
24	Register Bank 2		
16	Register Bank 1		
8	Register Bank 0		Default TOS
0			

The function of the various components of the on-chip RAM space and the addressing modes by which they may be accessed are discussed below.

2.3.1 Register Banks

The lower 32 bytes of the on-chip RAM space are divided into four register banks, usually associated with different interrupt nesting levels. The eight registers of the current bank, selected by two bits within the PSW, are usually used for scratchpad purposes.

2.3.2 Bit Space

The bit space contain 256 individually addressable bits. Bits 0 to 127 are mapped onto bytes 32 to 47 of the on-chip RAM space. Bits 128 to 255, some of which are nonexistent, are mapped onto some specific registers in the hardware space. Operations on the bit space include SET, CLEAR, COMPLEMENT, AND, OR and TEST.

2.3.3 Hardware Registers

When direct addressing is used, a few (20 for the 8051, 34 for the RUP1) of the top 128 bytes of the on-chip RAM space are mapped 1-1 onto a set of hardware registers (A, B, DPTR, etc.). Thus I/O and other accesses to the machine itself are accomplished by direct memory operations. The result of an access to an unoccupied location within that section is undefined.

2.3.4 Stack

The top of the stack is initially set by H/W to 07H (the start of register bank 1) but may be relocated to anywhere else within the on-chip RAM space by setting the Stack Pointer (SP).

The stack grows upward, i.e. the SP is incremented before a write operation (PUSH/CALL/ACALL instructions) and is decremented after a read operation (POP/RET/RETI instructions).

The stack is byte oriented. However when used in call/return-type operations, two bytes (a full 16 bit address) are pushed/popped.

2.3.5 Additional RAM (RUP1)

There are 64 bytes of additional on-chip RAM available on the RUP1 chip (locations 128 to 191). Other members of the family can have up to 128 additional on-chip Ram bytes. These additional bytes can only be accessed in the indirect addressing mode. They may be used as memory for the stack.

2.3.6 Addressing Modes

The on-chip RAM space can be accessed using the following addressing modes:

- a. Direct Addressing - the full 8 bit address is given in the second byte of the instruction. Addresses greater then 127 access the memory mapped hardware space.

- b. Indirect Register Addressing - the address is specified by the content of R0 or R1. Addresses greater than 127 address nothing on the 8051 and addresses greater than 191 address nothing on the RUP1.
- c. Register Addressing - a three bit field in the first (opcode) byte addresses a register within the current register bank.
- d. Bit Addressing - this is a direct addressing mode where the full (8-bit) bit address is given by the second byte of the instruction.
- e. Stack addressing - See 2.3.4.

3 REQUIREMENTS

3.1 Relocatable and External References

The OMF should support relocatable and external references of the following types:

- a. Low Byte - reference to the low-order byte of an address. Generated by the LOW operator or, for the DATA and BIT spaces, by a direct (full) address reference.
- b. High Byte - reference to the high-order byte of an address. Generated by the HIGH operator. Applicable to XDATA and CODE segments.
- c. Full CODE/XDATA Address - a full 16-bit reference.
- d. Inblock CODE Address - an 11-bit inblock reference.
- e. Relative CODE address - a reference +127/-128 relative to the PC (after it was incremented to the next instruction).
- f. Full Bit Address - an 8-bit bit address
- g. Mixed Byte/Bit Address - an 8-bit bit address of which only the (5-bit) byte address part is relocatable.

3.2 Segment Relocation

The object code will be organized in segments. The segments, defined by the user at translation time, will have the following attributes:

- a. Name - obeys the usual rules for assembly names.
- b. Segment type - the type of address space to which it belongs (DATA, XDATA, IDATA, CODE or BIT).
- c. Relocation type - one of the following types:
 - 1. Absolute - absolute segment. Cannot be relocated by the RL51 program.
 - 2. UNIT - a relocatable segment without any restriction concerning its ultimate location (located on a bit or byte boundary depending on the segment type).
 - 3. PAGE - a relocatable segment which must start on a 256 byte page boundary.
 - 4. INPAGE - a relocatable segment which must be contained within a 256 byte page.
 - 5. INBLOCK - a relocatable segment which must be contained within a 2048 byte block.

- 6. BITADDRESSABLE - a relocatable segment of type DATA which must be contained within the BIT space.
- d. Size - number of bytes in the segment (number of bits if it is of type BIT).
- e. Overlayability - each segment will be overlayable or not. Groups of overlayable segments may occupy the same memory locations if not accessed simultaneously. For example: overlayable segments are memory locations used for parameter passing in an HLL program.

The overlaying process involves determining the module call tree. Overlayable segments from (different) modules which have no calling link between each other can be overlaid. The united overlaid segment is considered a single segment for the allocation process.

The segments should be relocated and combined under the following rules:

- a. Segments with the same name should be combined by butting them up against one another. They must have the same segment type. Their relocation types must either be the same or a mixture of two types where one of the two is UNIT.
- b. The resulting segment should have the same name and type. Its relocation type will be that of its components or, if the components specify two types then one of them be UNIT and the result will be the more restrictive type. Its size will be the sum of the sizes of its components.
- c. The user should be able to assign an absolute location to the combined segment (unless it is an absolute segment).

3.3 Intermodule Linkage

The intermodule linkage will be based on the usual notion of a single public definition in one module and a number of external references in some other modules. The information supplied with the public and external symbols should enable the RL51 program to:

- a. Accomplish the two pass algorithm defined in the PIP for the 8051 R&L Package.
- b. Check symbol information matching between an external definition and a public definition.
- c. Set up the undetermined attributes of an external reference.
- d. Relocate an external reference.

3.4 Symbolic Debugging

The OMF should support the following debugging features:

- a. Provide name, segment and offset information for local and public symbols.
- b. Support symbolic debugging by statement numbers.
- c. Associate symbols and statement numbers with the module name in which they were defined.
- d. Provide means of conveying symbol names scope information.

3.5 Compatibility

All object files containing 8051 object code should adhere to the definition given in this document. In particular, the output of the assembler, the PL/M-51 compiler and the output of the RL51 program should adhere to this standard.

The absolute object file generated by the RL51 program will be defined by a proper subset of the OMF, called the Absolute Object Module Format (AOMF), defined in Appendix C. The AOMF will be compatible with the ISIS tools which processes files formatted as 8080 Absolute Object Module Format [4]: the OBJHEX and the UPM programs.

A stand-alone assembly program without any relocatable segments and external references will also be translated by the RASM into an AOMF type object file.

A new version of the ICE51 is desired, which will accept AOMF type files. Until then the OBJHEX program will be used to convert these files into the current ICE51 format. Note that OBJHEX purges all debug information present in its input object file.

The OMFs should contain hooks to allow the addition of library facilities.

3.6 RUP1 (And other MCS-51 members) Support

From RL51 viewpoint, members of the MCS-51 family differ from each other only by the amount of additional on-chip RAM available. This space is available in the RASM via segments of type IDATA. This information must be supplied to RL51 in order to be able to check the RAM requirements can be satisfied.

4 OBJECT FILE STRUCTURE

An object file is defined by a sequence of records. The following syntax shows what sequences of records are valid, and the following semantics gives important information that is conveyed by the sequence, rather than mere content, of records. Definition of valid string of records is given by the following syntax: (Note: <ITEM>* means that the <ITEM> can occur zero or more times.)

```

<object file>      ::=  <module>* | <library>

<module>           ::=  MODULE_HEADER_RECORD
                        <definition record>*
                        <data/debug record>*
                        MODULE_END_RECORD

<definition record> ::=  SEGMENT_DEFINITIONS_RECORD
                        | PUBLIC_DEFINITIONS_RECORD
                        | EXTERNAL_DEFINITIONS_RECORD

```

<data/debug record>	::=	<data section> <debug record>
<debug record>	::=	SCOPE_DEFINITION_RECORD DEBUG_ITEMS_RECORD
<data section>	::=	CONTENT_RECORD FIXUP_RECORD*
<library>	::=	LIB_HEADER_RECORD <module>* LIB_MODULE_NAMES_RECORD LIB_MODULE_LOCATIONS_RECORD LIB_DICTIONARY_RECORD

An object file can be a sequence of modules or a library. A module consists of a pair of Module Header and Module End records enclosing the module body. The body of the module consists of a definition part and a sequence of debug records and data sections.

The definition part contains a set of records which specifies the segment within the module, the public symbols which resides in the module and the external names used in it.

Debug records contain Debug Items Records about segment symbols, publics symbols, symbols local to the module and the location of the higher level statements ('line numbers'). They may possibly be enclosed within a pair of Scope Definition Records.

A data section consists of a Content Record which is an image of a section of code and a set of Fixup records which are used by the RL51 program to relocate that section and resolve external references contained in it.

A library file consists of a Library Header Record followed by a set of modules and terminated by three records. These last records list the names of the modules, their location in the file and the lists of the public symbols defined in each of the modules.

5 RECORD FORMATS

5.1 Notation

The object file is a set of typed records, described in detail in the rest of this chapter. To visualize a given record format, the following typical scheme is used:



Each format is drawn with boxes of two sizes. the narrow boxes, outlined entirely, represent single bytes. The wide boxes, outlined entirely, represent two bytes each.

The wide boxes, but with double lines on top and bottom, represent a variable number of bytes, one or more depending on content.

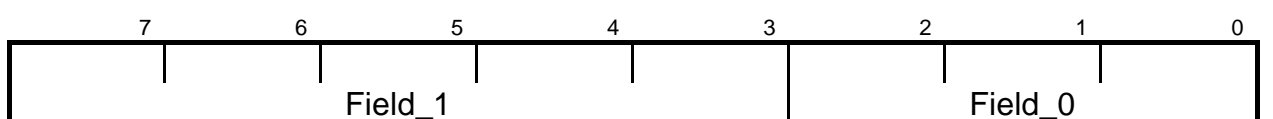
Any field that indicates NAME has the following internal structure: the 1st byte contains a number between 0 and 40, inclusive, that indicates the number of remaining bytes in the field. The remaining bytes are interpreted as a byte string; each byte must represent a member of the following subset of the ASCII character set: {upper case letters (A..Z), decimal digits (0..9), the special characters "_", "?" and "@"}.

Some portions of a record may be repeated 0 or more times. These are indicated "repeated" or "rept" below the boxes.

The shaded fields are fields which carry no information. They are present to enable future enhancements (e.g. SYMBOL TYPE fields) or for compatibility reasons and should have a zero value.

Each record starts with a record type which indicates the type of the record, and record length which contain the number of bytes in the record exclusive of the first two fields. The record ends with a checksum byte which contains the 2's complement of the sum (modulo 256) of all other bytes in the record. Therefore the sum (modulo 256) of all bytes in the record is zero.

Some byte fields contain bit subfields. To describe them the following scheme is used:



In the above example the byte contain two fields: FIELD_1 from bit 3 to bit 7 and FIELD_0 from bit 0 to bit 2.

In the following sections an absolute address is a 16 bit integer representing an offset from the beginning of the corresponding address space, in bits for a BIT type and in bytes otherwise. An OFFSET field is a 16 bit integer representing an offset from the beginning of the corresponding segment, in bits for a BIT type and in bytes otherwise.

In the following record descriptions, whenever a field can assume only a discrete set of values (e.g. TRN ID in Module Header record), the unused values are reserved for future expansion. In particular, unused record types are reserved for future use.

5.2 Module Header Record

REC TYP 02H	Record Length	Module Name	TRN ID		CHK SUM
-------------------	------------------	----------------	-----------	--	------------

Each module must start with a module header record. It is used to identify the module for the RL51 and other future processors of 8051 object files. In addition to the Module Name the record contains:

TRN ID

The byte identifies the program which has generated this module: 0FDH - ASM51, 0FEH - PL/M-51, 0FFH - RL51.

5.3 Module End Record

REC TYP 04H	Record Length	Module Name		REG MSK		CHK SUM
-------------------	------------------	----------------	--	------------	--	------------

The record ends the module sequence and contains the following information: characteristics

MODULE NAME

The name of the module is given here for a consistency check. It must match the name given in the Module Header Record.

REGISTER MASK (REG MSK)

The field contains a bit for each of the four register banks. Each bit, when set specifies that the corresponding bank is used by the module:

Bit 0 (the least significant bit) - bank #0.

Bit 1 - bank #1.

Bit 2 - bank #2.

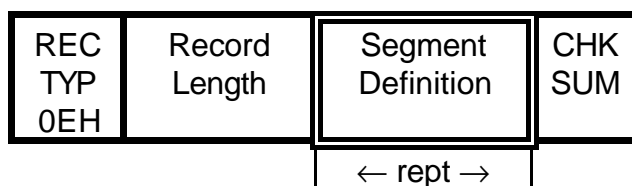
Bit 3 - bank #3.

5.4 Definition Records

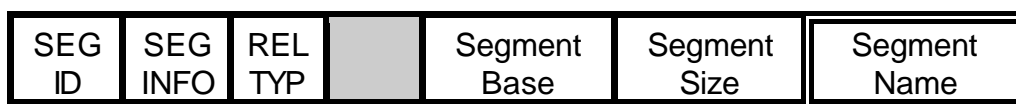
The definition part contains the names and other attributes of the segments, publics and externals used in the module.

The definition part consists of three types of records: Segment Definitions Record, Public Definitions Record and External Definitions Record.

5.4.1 Segment Definitions Record



The record defines segments which are used in the module. The record contains a repetition of segment definitions. Forward references to a segment definition are not allowed. The structure of each segment definition is as follows:



SEG ID

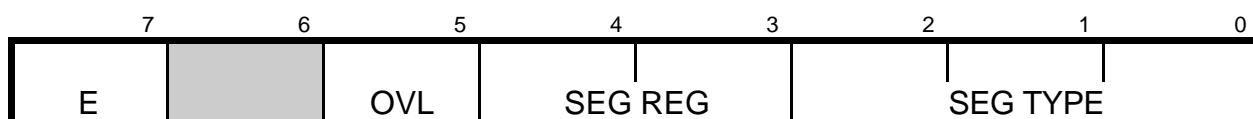
The field can have the following values:

- 0 - identifies an absolute segment. Absolute references, within the object module, do not refer to an absolute segment definition. Absolute segments cannot be combined and have null (zero length) names.
- 1 to 255 - identifies a relocatable segment; (SEG ID - 1) must be equal to the sequential number of its definition in the list of the segment definition as they appear in the module (ignoring the absolute segment definitions!).

Thus the OMF allows for up to 255 relocatable segments and an arbitrary number of absolute segments to be defined within a module.

SEG INFO (segment information)

The structure of this field is as follows:



E

This bit specifies (when set) that the segment is of zero size (empty).

_____ OVL

This bit specifies (when set) that the segment is overlayable (i.e. RL51 may overlay this segment by other compatible overlayable segments).

_____ SEG REG

This field specifies the register bank in which the overlayable segment may be used. The field is meaningful only for overlayable segments.

Bits 3 and 4 have the following meaning:

_____ 00 - register bank # 0.

_____ 01 - register bank # 1.

_____ 10 - register bank # 2.

_____ 11 - register bank # 3.

The combination of non-zero SEG REG for nonoverlayable segments is reserved for future use.

SEG TYPE

This field specifies the type of the segment:

0 - CODE.

1 - XDATA.

2 - DATA.

3 - IDATA.

4 - BIT.

REL TYP (relocation type)

The relocation type field of a segment can specify an absolute segment and four types of relocatable segments:

0 - ABS. Specifies an absolute segment (non-relocatable).

1 - UNIT. The segment can be relocated on a unit boundary (a bit boundary for BIT type segments and a byte boundary for all other segments). Thus no restrictions are placed on its relocation.

2 - BITADDRESSABLE. The segment must be located within the bit-addressable portion of the internal data space. Allowed only for DATA type segments.

3 - INPAGE. The segment will be located within a 256 byte page.

4 - INBLOCK. The segment will be located within a 2048 byte block.

- 5 - PAGE. The base address of this segment will be on a 256 byte page boundary.

The types INPAGE and PAGE are valid only for the CODE and XDATA segment types. INBLOCK is valid only for the CODE segment type.

SEGMENT BASE

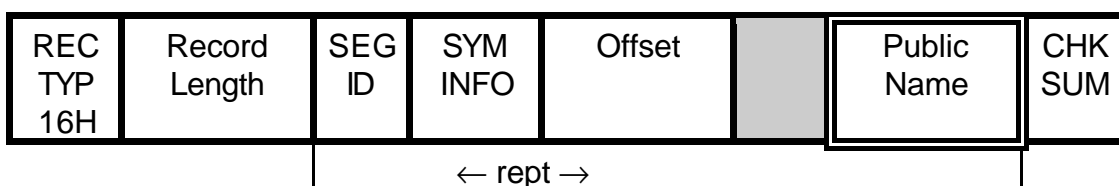
This field gives the absolute address of the segment. It is used for absolute segments only. For relocatable segments this field contain zero.

SEGMENT SIZE

The number of bytes (or bits in the case of BIT type segment) occupied by the portion of the segment defined in this module. A value of zero specifies a size of 10000H (64K) bytes. This field is ignored if the segment is empty (E is set).

SEGMENT NAME

The name of the segment. Since absolute segments have no names, the field in their case specifies a null name (zero length).



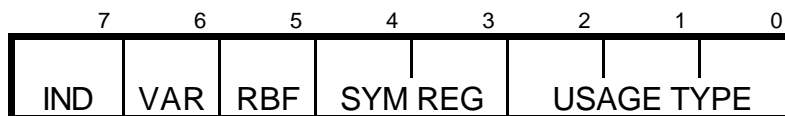
This record defines public symbols used in the module.

SEG ID

- 0 - identifies an absolute (non-relocatable) symbol.
 1 to 255 - identifies a relocatable symbol. The value specified identifies the segment definition containing the public symbol (see 5.4.1).

SYM INFO (symbol information)

The structure of this field is as follows:



____IND (indirectly_callable)

This bit specifies (when set) that the procedure is indirectly callable. This field is meaningful only for public procedure symbols.

____ VAR

This bit specifies (when set) that the public symbol is a variable (i.e. not a procedure).

____ RBF (register bank flag)

This bit specifies (when set) that symbol register (SYM REG) field is valid, i.e. when the bit is not set all register banks may be used by the procedure. This field is meaningful only for public procedure symbols.

____ SYM REG

This field specifies the register bank which is used in the procedure. The field is meaningful only for procedure symbols.

Bits 4 and 5 have the following meaning:

____ 00 - register bank # 0.

____ 01 - register bank # 1.

____ 10 - register bank # 2.

____ 11 - register bank # 3.

The combination of non-zero SYM REG for nonprocedure symbols is reserved for future use.

USAGE TYPE (USG TYP)

This field specifies the usage of the symbol:

0 - CODE address.

1 - XDATA address.

2 - DATA address.

3 - IDATA address.

4 - BIT address.

5 - NUMBER. A typeless number. Can match any external symbol and be used in any context.

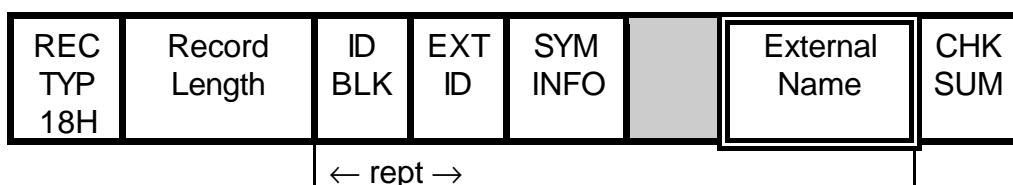
OFFSET

For absolute symbol the field gives the absolute address of the symbol within its address space. For relocatable symbol the field gives the offset of the symbol from the segment identified by the SEG ID. For NUMBER symbol, it gives its value.

PUBLIC NAME

The field gives the name of the public symbol. The name should be unique within each relocation and linkage process.

5.4.2 External Definitions Record



The record provides a list of external names and their assumed segment type. The External Names Records form, by their internal order and the order of their appearance, a sequential list of external symbols. Further references to an external symbol (the EXT ID field) are implemented as the index of its entry in that list.

The OMF allows up to 256 external symbols per module.

ID BLK and EXT ID

This pair specifies the index of the external symbol definition entry in the external symbol list (see above). The ID BLK identifies to what block of 256 external symbols the EXT ID belongs. Currently it must contain 2. The EXT ID field gives the index of the entry definition in that block. EXT ID must be equal to the sequential number (0,1,...) of the definition in the module.

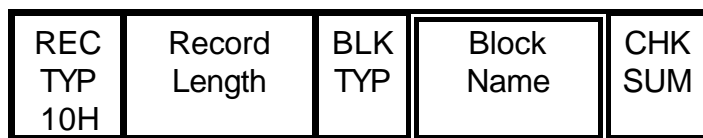
____SYM INFO (symbol information)

This field is equivalent to public definition SYM INFO (see 5.4.2) except that IND bit is always 0. NOTE that this field gives the information about the symbol as given to the translator at the symbol declaration.

5.5 Debug Records

This is a group of records which appears in the object file if the user has requested the debug option from the translator or RL51.

5.5.1 Scope Definition Record



This record is used to limit the scope of symbols and line numbers, found in Debug Items Records, to the block in which they were defined in the source program.

BLK TYP

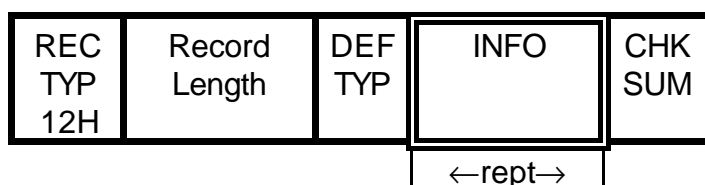
This field can assume the following values:

0. module block. Generated once for each module. This type of Scope Definition Record should be the first debug record in the module, since it encloses (with its respective Module-End type Scope Definition Record) the whole debug information in the module.
1. DO block. Generated for each simple DO statement which contains declarations in its block.
2. PROCEDURE block. Generated for each PROCEDURE statement which contains declarations in the procedure's block.
3. Module end. Generated for each END statement which closes module. The BLOCK NAME in this record must match the name of the last module scope definition.
4. DO end. Generated for each END statement which closes DO block. The BLOCK NAME in this record must match the name of the last opened DO scope definition.
5. PROCEDURE end. Generated for each END statement which closes PROCEDURE block. The BLOCK NAME in this record must match the name of the last opened PROCEDURE scope definition.

BLOCK NAME

The name (label) of the block.

5.5.2 Debug Items Record



The record provides information on segment symbols, public symbols, line numbers and symbols local to the module/DO block/procedure (see 5.5.1). It is intended for use by the ICE and other debug tools.

DEF TYP

The field specifies what items are being defined in this record:

- 0 - Local symbols.
- 1 - Public symbols. This kind of items should not appear within a DO blocks or PROCEDURES blocks.
- 2 - Segment symbols.
- 3 - Line numbers (in the current module).

INFO

The structure of this field depends on DEF TYP. The INFO field for local or public symbols gives the location and the name of a symbol:



For segment symbols the INFO field gives the location and the name of the symbol.



SEG ID

See 5.4.1.

SYM INFO (symbol information)

See 5.4.2.

SEG INFO (segment information)

See 5.4.1.

OFFSET

See 5.4.2. For segment symbol this field is meaningful only after the R&L process. Then it gives the absolute base address of the segment.

SYMBOL NAME

The name of the symbol.

The INFO field for a line number associates a physical location with a line number (statement number) in the source code:

SEG ID	Offset	Line Number
-----------	--------	----------------

SEG ID

See 5.4.2. Must identify a CODE type segment.

OFFSET

Gives the location (see 5.4.2) of the first byte of code which was compiled from the statement.

LINE NUMBER

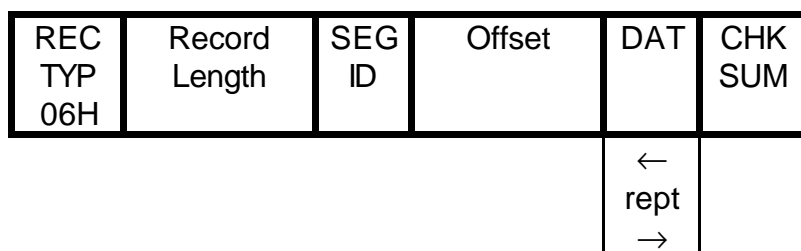
The line number in a binary representation.

5.6 Data Section

The actual memory image of the program is given in the OMF in groups of records called data sections.

A data section consists of a Content Record, followed by a sequence of fixup records which operates on it.

5.6.1 Content Record



This record provides one or more bytes of contiguous data, from which a portion of a memory image may be constructed.

SEG ID

This field identifies the segment which contains the data (see 5.4.1). The type of this segment must be CODE.

OFFSET

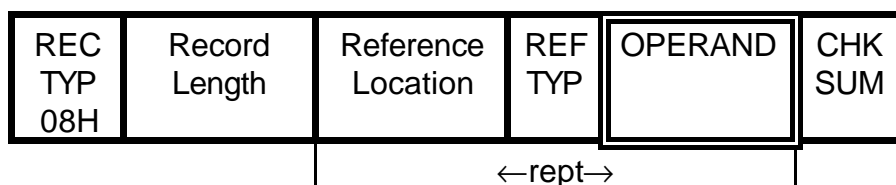
Gives the location of the first byte of data in the record, relative to the beginning of the portion of the segment defined in the module (or to zero if it is an absolute segment).

DAT

A sequence of data bytes. If n is the number of data bytes in the record then $OFFSET + n$ should be less than or equal to the size of the segment as defined in the Segment Definitions Records (unless the segment is absolute).

Zero or more of the data bytes form references to relocatable or external symbols. Those bytes should be fixed up by the RL51 program using information provided in the following Fixup records.

5.6.2 Fixup Record



A Fixup Record specifies a set of fixups which should be applied on references within the previous Content Record (referred here as PCR). A fixup is specified by the location of the reference, its type and the operand which is evaluated into a 16 bit value (modulo 64K without an overflow check) referred below as ADDR (usually the address of the target).

The reference type should then be used in order to determined how this value should be converted into its final form in the PCR.

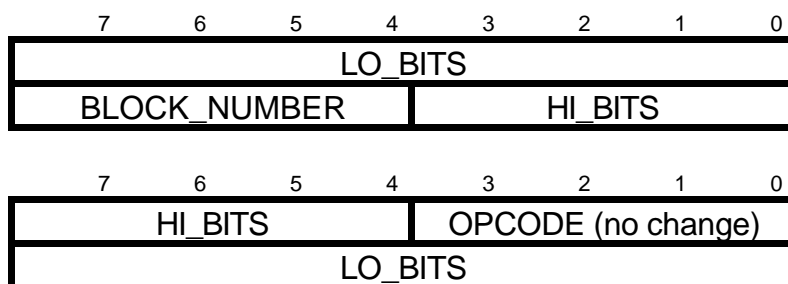
REFERENCE LOCATION

The field gives the location of the first byte of the reference relative to the beginning of the data portion of the PCR. The complete reference (one or two bytes) specified by this field must be within that data portion. The location of the reference is referred below as REFLOC.

REF TYP

This field specifies the type of the reference that should be fixed. The field can assume the following values:

- 0 - LOW. The low-order byte of ADDR is stored at REFLOC.
- 1 - BYTE. The low-order byte of ADDR is stored at REFLOC. The high-order byte of ADDR must be zero.
- 2 - RELATIVE. The absolute CODE address of REFLOC should be subtracted from ADDR. The result should be a 2's complement value between +127 to -128. The low-order byte of the result is stored at REFLOC.
- 3 - HIGH. The high-order byte ADDR is stored at REFLOC.
- 4 - WORD. The high-order of ADDR is stored at REFLOC. The low order part is stored at REFLOC+1.
- 5 - INBLOCK. The 3 low-order bits of the high-order byte of ADDR (HI_BITS) are stored in the 3 high-order bits at REFLOC. The low-order byte (LO_BITS) is stored at REFLOC+1. The 5 high-order bits in the high-order byte of ADDR (BLOCK_NUMBER) must be the same as the corresponding bits in the absolute address corresponding to REFLOC+2. This somewhat complex task is shown in the following figure:



- 6 - BIT. ADDR should be in the range of 0 to 127 (the internal RAM portion of the bit space). The low-order byte of ADDR is stored at REFLOC.
- 7 - CONV. This type specifies an address of a bit in a bit_addressable byte. After computing ADDR (the special ADDR computation is described below), it is treated as in the above BIT case.

OPERAND

The structure of this field is as follows:

ID BLK	ID	Offset
-----------	----	--------

The OPERAND triplet (ID BLK, ID, OFFSET) specifies the operand of the reference calculation, evaluated into the 16 bit value called ADDR. It is logically composed of two components: BASE, defined by the two fields ID BLK and ID, and OFFSET.

BASE is defined as follows:

ID BLK = 0: segment operand.

BASE is set to the absolute base address of the segment identified by ID (i.e. ID is interpreted here as SEG ID).

ID BLK = 1: relocatable operand.

BASE is set to the absolute base address of the PSEG. I.E., that portion of the segment defined in the current module. The segment is again identified by ID.

ID BLK = 2: external operand.

BASE is set to the absolute base address of the public symbol specified by the external symbol. The external symbol is identified by ID. (i.e. ID is interpreted here as EXT ID).

ID BLK = 3 to 255: reserved for future expansion.

The way ADDR is calculated from BASE and OFFSET is as follows:

```

IF REF_TYPE = CONV THEN
    ADDR = (BASE - 20H)*8 + OFFSET;
ELSE
    ADDR = BASE + OFFSET;

```

5.7 Library Records

The 8051 object library file is structured identically to that of the OMF80/85, i.e. a Library Header Record followed by a sequence of modules and terminated by a library tail. The record format of the library records is also identical to the corresponding OMF80/85 records.

5.7.1 Library Header Record

REC TYP 2CH	Record Length	Module Count	Block Number	Byte Number	CHK SUM
-------------------	------------------	-----------------	-----------------	----------------	------------

This record is the first record in a library file. It immediately precedes the modules (if any) in the library. Following the modules (if any) are 3 more records in order: Library Module Names Record, Library Module Location Record and Library Dictionary Record.

MODULE COUNT

This field indicates how many modules are in the library. It may have any value from 0 to 65535, inclusive.

BLOCK NUMBER, BYTE NUMBER

These fields indicate the relative location of the first byte of the Library Module Names Record in the library file.

5.7.2 Library Module Names Record

REC TYP 28H	Record Length	Module Name	CHK SUM
←rept→			

This record gives the names of all the modules in the library. The order of the names corresponds to the order of the modules in the library. Only one Library Module Names Record may appear in the library.

MODULE NAME

The i'th MODULE NAME field in the record contains the name of the i'th module in the library.

5.7.3 Library Module Locations Record

REC TYP 26H	Record Length	Block Number	Byte Number	CHK SUM
←rept→				

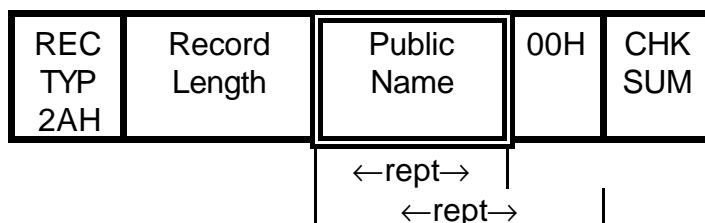
This record provides the relative location, within the library file, of the first byte of (the Module Header Record of) each module. Only one record of this kind may appear in the library.

The order of the block-number/byte-number pairs corresponds to the order of the modules within the library.

BLOCK NUMBER, BYTE NUMBER

The i'th pair of fields provides the relative location, within the library file, of the first byte of the first record of the i'th module within the library.

5.7.4 Library Dictionary Record



This record gives all the names of the public symbols within the modules in the library. Only one record of this kind may appear in the library.

Since a name must have a non-zero length, the '00' bytes in the format are distinguishable from the PUBLIC NAME fields. Thus, the '00' bytes separate the public names into groups; all names in the i'th group are defined in the i'th module in the library.

PUBLIC NAME

This is the name of a public symbol in the module. No public symbol may appear more than once in this record.

APPENDIX A: RECORD FORMAT SUMMARY

In order to provide a compact summary the following notation was adopted:

REC TYPE - the record type field of the record.
 TITLE - a free abbreviation of the name of the section describing this record.
 RECORD FORMAT - The body of the record (excluding the type, length and checksum fields), described as a sequence of fields. Repetition is specified by an item or items enclosed in parentheses followed by an asterisk. Field names were freely abbreviated.
 FIELDS LENGTH - the lengths of the fields given in the order of the fields in the RECORD FORMAT field. **B** stands for byte field, **W** for word and **N** for name field (its length is defined by the first byte of the field).

REC TYPE	TITLE	RECORD FORMAT	FIELDS LENGTH
02H	Module HDR	MODNAM, TRNID, X	N, B, B
04H	Module END	MODNAM, X, REGMSK, X	N, W, B, B
06H	Content	SEGID, OFFSET, (DATA)*	B, W, B
08H	Fixup	(REFLOC, REFTYP, IDBLK, ID, OFFSET)*	W, B, B, B, B, W
0EH	Segment DEF	(SEGID, SEGINFO, RELTYP, X, SEGBAS, SEGSIZ, SEGNAM)*	B, B, B, B, W, W, N
10H	Scope DEF	BLKTYP, BLKNAM	B, N
12H	Debug Item	0, (SEGID, SYMINFO, OFFSET, X, LOCNAM)* 1, (SEGID, SYMINFO, OFFSET, X, PUBNAM)* 2, (SEGID, SEGINFO, OFFSET, X, SEGNAM)* 3, (SEGID, OFFSET, LINENUM) *	B, B, B, W, B, N B, B, B, W, B, N B, B, B, W, B, N B, B, W, N
16H	Public DEF	(SEGID, SYMINFO, OFFSET, X, PUBNAM)*	B, B, W, B, N
18H	External DEF	(IDBLK, EXTID, SYMINFO, X, EXTNAM)*	B, B, B, B, N
26H	LIB ModLocs	(BLKNO, BYTEN0)*	W, W
28H	LIB ModName	(MODNAM)*	N
2AH	LIB DICTNRY	((PUBNAM)*, 0)*	N, B
2CH	LIB Header	MODCOUNT, BLKNO, BYTEN0	W, W, W

APPENDIX B: GLOSSARY

The terms explained in this section were selected because of their possible special local meaning within the context of the 8051 machine and the 8051 S/W support package.

RL51	- the 8051 Relocation and Linkage program.
RASM	- the 8051 Relocating Assembler.
Module	- a self-contained unit of compilation/assembly.
PC	- the Program Counter.
DPTR	- the Data pointer.
A	- the Accumulator.
Segment	- A contiguous section in the memory. Contains data or code.
Address space	- An ordered set of memory locations which can be reached by a set of addressing modes.
CODE	- the Code address space.
DATA	- that part of the internal RAM which is accessible in direct addressing.
XDATA	- the External Data address space.
BIT	- the Bit address space within the DATA space.
IDATA	- that part of the internal RAM which is accessible in indirect addressing.
Page	- a 256 byte contiguous section beginning on an address whose 8 low-order bits are zero.
Block	- a 2048 byte contiguous section beginning on an address whose 11 low-order bits are zero.
INPAGE	- a relocation type in which the segment must completely reside within a 256 byte page.
INBLOCK	- similar to INPAGE. Block size is 2048 bytes.
BITADDRESSABLE	- a relocation type that specifies that the segment must reside within the bit space. Used for DATA type segments.
UNIT	- a relocation type where the segment may reside anywhere in its address space (base address on a unit boundary).
PAGE	- a relocation type where the segment starts on a boundary of a 256 byte page.
ABS	- a relocation type specifying an absolute segment.
SEG ID	- segment identification. A byte which specifies the index of the segment entry in the segment table as given in the Module Header Record.
Reference	- the fields within an instruction which point to its operand.
Target	- the operand pointed at by a reference.
OMF	- the Object Module Format for the 8051.
AOMF	- a subset of the OMF which is the format of the object files produced by RL51 (and the RASM if the source program is absolute).
NUMBER	- a symbol which refer to no segment and therefore may match all types of symbols.

APPENDIX C: ABSOLUTE OBJECT MODULE FORMAT

The Absolute Object Module Format (AOMF) is a subset of the 8051 OMF. The structure of an absolute object file (the order of the records in it) is similar to that of a relocatable object file. There are three main differences: the first is that an absolute object file contains one module only, the second is that not all the records can appear in the absolute file and the third is that the records can contain only absolute information.

The following sections use the same notation described in section 4 and 5.1.

C.1 Structure Of Absolute Object File

```

<absolute object file>      ::=    <module>

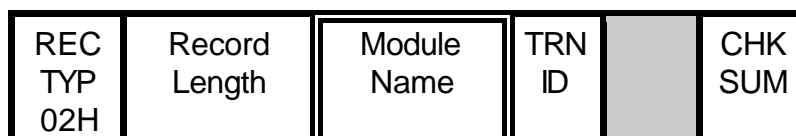
<module>                    ::=    MODULE_HEADER_RECORD
                                   <data/debug record>*
                                   MODULE_END_RECORD

<data/debug record>         ::=    CONTENT_RECORD
                                   | <debug record>

<debug record>              ::=    SCOPE_DEFINITION_RECORD
                                   | DEBUG_ITEMS_RECORD
  
```

The records with the following types are extraneous (they may appear in the file but are ignored): 0EH, 16H and 18H (definition records). All records which are not part of the AOMF and are not extraneous are considered erroneous.

C.2 Module Header Record

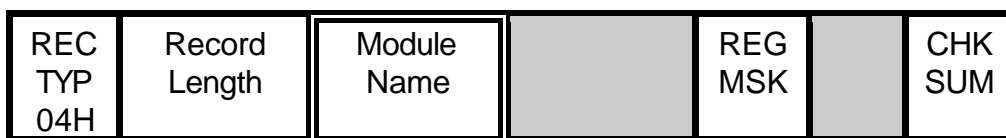


Each module must start with a module header record. It is used to identify the module for the RL51 and other future processors of 8051 object files. In addition to the Module Name the record contains:

TRN ID

The byte identifies the program which has generated this module: 0FDH - ASM51, 0FEH - PL/M-51, 0FFH - RL51.

C.3 Module End Record



The record ends the module sequence and contains the following information: characteristics

MODULE NAME

The name of the module is given here for a consistency check. It must match the name given in the Module Header Record.

REGISTER MASK (REG MSK)

The field contains a bit for each of the four register banks. Each bit, when set specifies that the corresponding bank is used by the module:

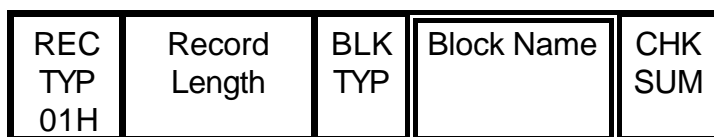
Bit 0 (the least significant bit) - bank #0.

Bit 1 - bank #1.

Bit 2 - bank #2.

Bit 3 - bank #3.

C.4 Scope Definition Record



This record is used to limit the scope of symbols and line numbers, found in Debug Items Records, to the block in which they were defined in the source program.

BLK TYP

This field can assume the following values:

0 - module block. Generated once for each module. This type of Scope Definition Record should be the first debug record in the module, since it encloses (with its

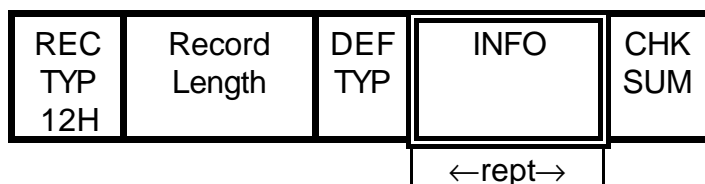
respective Module-End type Scope Definition Record) the whole debug information in the module.

- 1 - DO block. Generated for each simple DO statement which contains declarations in its block.
- 2 - PROCEDURE block. Generated for each PROCEDURE statement which contains declarations in the procedure's block.
- 3 - module end. Generated for each END statement which closes module. The BLOCK NAME in this record must match the name of the last module scope definition.
- 4 - DO end. Generated for each END statement which closes DO block. The BLOCK NAME in this record must match the name of the last opened DO scope definition.
- 5 - PROCEDURE end. Generated for each END statement which closes PROCEDURE block. The BLOCK NAME in this record must match the name of the last opened PROCEDURE scope definition.

BLOCK NAME

The name (label) of the block.

C.5 Debug Items Record



The record provides information on segment symbols, public symbols, line numbers and symbols local to the module/DO block/procedure (see 5.5.1). It is intended for use by the ICE and other debug tools.

DEF TYP

The field specifies what items are being defined in this record:

- 0 - Local symbols.
- 1 - Public symbols. This kind of items should not appear within a DO blocks or PROCEDURES blocks.
- 2 - Segment symbols.
- 3 - Line numbers (in the current module).

INFO

The structure of this field depends on DEF TYP. The INFO field for local or public symbols gives the segment type, info, location and the name of a symbol:



The INFO field for segment symbols gives the segment type, info, location and the name of a symbol:



_____ SEG ID

This field must be zero.

_____ SYM INFO (symbol information)

See 5.4.2.

SEG INFO (segment information)

See 5.4.1.

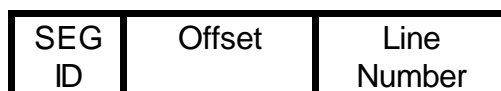
OFFSET

The field gives the absolute address of the symbol in the address space specified by SEG INFO or SYM INFO. For segment symbols this field gives the base address of the segment. The offset is given in bits for symbols with usage type equal to BIT and in bytes otherwise.

SYMBOL NAME

The name of the symbol.

The INFO field for a line number associates a absolute location with a line number (statement number) in the source code:



SEG ID

Must be zero.

OFFSET

Gives the absolute address, in the CODE address space, of the first byte of code which was compiled from the statement.

LINE NUMBER

The line number in a binary representation.

C.6 Content Record

REC TYP 06H	Record Length	SEG ID	Offset	DAT	CHK SUM
				← rept →	

This record provides one or more bytes of contiguous data, from which a portion of a memory image may be constructed.

SEG ID

This field must be zero.

OFFSET

Gives the absolute address of the first byte of data in the record, within the CODE address space.

DAT

A sequence of data bytes to be loaded from OFFSET to OFFSET+RECORDLENGTH-5.

APPENDIX D: DOCUMENT HISTORY

This appendix is provided to preserve the order and reasons for changes in the document.

1. EXTERNAL PRODUCT SPECIFICATION FOR THE 8051 OBJECT MODULE FORMATS, VERSION X207. April 12, 1982.

This version eliminates the machine mask field from Module End Records.

2. EXTERNAL PRODUCT SPECIFICATION FOR THE 8051 OBJECT MODULE FORMATS, VERSION V5.0. Sept. 05, 1982.

This is the final version submitted with RL51 V2.0 and PL/M-51 V1.0.

APPENDIX E: REFERENCES

- [1] "MCS 80/85 RELOCATABLE OBJECT MODULE FORMATS", Intel Manual.
- [2] "EXTERNAL REFERENCE SPECIFICATIONS, 8086 OBJECT MODULE FORMATS", December 4, 1978.
- [3] "8051 Relocation and Linkage", Feb. 1, 1980.
- [4] "MCS 80/85 Absolute Object File Formats", Intel Manual #9800183B.