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1 Introduction to Emacs Lisp Byte Code and LAP

1.1 Why is Emacs Lisp Byte Code Important and How is Emacs as a Program Different?

If you were to look at two comparable complex programs circa 2018, Firefox 53.0.3 and Emacs 25.3, you would see that relative sizes of Firefox tarball is 5 times bigger than for Emacs. But how are these made up, or what languages are they comprised of?

For Firefox whose core is written in C++ we have:

```
$ cloc --match-f='\.(js|c|cpp|html|py|css)$' firefox-53.0.3
   89156 text files.
   86240 unique files.
    1512 files ignored.

cloc v 1.60  T=244.20 s (353.2 files/s, 56012.8 lines/s)
-------------------------------------------------------------
Language                     files     comment           code
-------------------------------------------------------------
C++                           7267      418019        3057110
Javascript                   25855      532629        2859451
HTML                         45311      120520        2209067
C                             3482      400594        1664666
```

And for Emacs whose core is written in C we have:

```
$ cloc emacs-25.3.tar.xz
    3346 text files.
    3251 unique files.
    1130 files ignored.

cloc 1.60  T=13.85 s (160.1 files/s, 154670.7 lines/s)
-----------------------------------------------------------------
Language                      files     comment           code
-----------------------------------------------------------------
Lisp                           1616      200820        1270511
C                               255       66169         256314
C/C++ Header                    176       11505          34891
```

If you look at the relative ratio of C++ versus Javascript code in Firefox, and the ratio of C versus Lisp code in Emacs, you'll see that there is much more of Emacs written in Lisp than say of Firefox written in Javascript. (And if you look at the C code for Emacs, a lot of it looks like Lisp written using C syntax). My take is that Emacs a lot more orthogonal in its basic concepts and construction. Just as Leibniz was amazed that such diversity could come out of such simple rules of mathematics and physics, so it is remarkable that something as complex as Emacs can come out of the relatively simple language Lisp.

1.2 Emacs Lisp Byte Code and LAP

However pervasively used, Emacs Lisp is in making up the Emacs ecosystem, Emacs Lisp is not and never has been a speedy language compared to say, C, C++, Go, Rust, or Java. And that's where LAP and bytecode come in.

As stated in a commment in `byte-opt.el` added circa 1996:

> No matter how hard you try, you can't make a racehorse out of a pig.
>
> You can, however, make a faster pig.
>
> —*Eric Naggum*

Emacs Lisp bytecode is the custom lower-level language used by Emacs' bytecode interpreter. As with all bytecode, bytecode instructions are compact. For display purposes, there is a `disassemble` command that unpacks the fields of the instruction. With this and the constants vector, bytecode can be printed in an assembly-language-like format.

I'll often use Emacs Lisp bytecode instruction refer to an assembly representation of an Emacs Lisp bytecode instruction.

LAP stands for Lisp Assembly Program. It is an internal representation of the bytecode instructions in a more symbolic form. It is used behind the scenes to that make bytecode more amenable to optimization, since the instructions are in a structure which is easier to operate on.

If you want to write the instruction sequence in this symbolic form rather than give a byte-encoded form, you can do that using the function `byte-compile-lapcode`.

Example showing use of `byte-compile-lapcode`

```
(defalias 'get-foo
  (make-byte code
    #x000                   ;; lexical parameter counts
    (byte-compile-lapcode
      '((byte-varref . 0)
        (byte-return)))     ;; instruction sequence
    [foo]                   ;; constants vector
    1))                     ;; max stack usage
```

Silly Loop Example (`https://www.gnu.org/software/emacs/manual/html_node/elisp/Speed-of-Byte_002dCode.html`) in the Emacs Lisp Manual gives a program to time running in some code Bytecode interpreter versus running the code in the Lisp interpreter. When I ran this program, bytecode ran 2.5 times faster[1]. The Emacs Lisp manual gets a speed improvement of about 3 times.

[1] Code was compiled to use dynamic binding for variable access, same as was probably used in the Emacs Lisp manual. We should note that, byte-compiling with lexical binding for variable access gives code that runs a bit faster than when dynamic binding is used.

1.3 Emacs Lisp Virtual Machine

The Emacs Lisp bytecode interpreter, like many bytecode interpreters such as Smalltalk, C Python, Forth, or PostScript, has an evaluation stack and a code stack. Emacs Lisp Bytecode instructions come in the order used in Reverse Polish Notation: operands appear prior to the operator. This is how many other bytecode interpreters work. It is the opposite of the way Lisp works. Thus, to add the values of two variables we might write `(+ a b)`. However in bytecode it is the other way around: the operator or function comes last. So the corresponding bytecode is:

```
0       varref    a
1       varref    b
2       plus
```

As in most language-specific virtual machines, but in contrast to a typical a number of general-purpose virtual machines, the things that are on the evaluation stack are the same objects as found in the system that they model. Here, these objects can include Emacs buffers, or font faces, Lisp objects like hashes or vectors, or simply (30-bit) Lisp integers. Compare this with say LLVM IR, or JVM instructions where the underlying objects on the stack are registers which can act as pointers and the internal memory layout of objects is exposed.

Control flow in Lisp bytecode is similar to a conventional assembly language: there are unconditional and conditional jumps. More complex control structures are simply built out of this.

Although it may be obvious, one last thing I'd like to point out is that the Emacs Lisp bytecode instruction set is custom to Emacs. In addition to primitives that you'd expect for Lisp like "car" and "cdr", there are primitive bytecodes for more complex Emacs editor-specific concepts like "save-excursion"[1].

The interpreter is largely backwards compatible, but not forwards compatible[2]. So old versions of Emacs can't run new byte code. Each instruction is between 1 and 3 bytes. The first byte is the opcode and the second and third bytes are either a single operand, a single immediate value. Some operands are packed into the opcode byte.

[1] The fact that the semantic level difference between Emacs Lisp and its bytecode is not great makes writing a decompiler for it more feasible than if the bytecode language were of a general nature such as say LLVM IR.

[2] well, eventually old Emacs Lisp bytecode instructions *do* die

2 Emacs Lisp Byte-Code Environment

In this chapter we will discuss the ways Emacs creates, modifies and uses bytecode in order to run code. We describe a little of the two kinds of interpreters Emacs has, what goes into a bytecode file, and the interoperability of bytecode between versions.

2.1 Byte-Code Objects

This section is largely lifted from Chris Wellons' Emacs byte code Internals and the Emacs Lisp Reference manual. See references at the end of this doc.

Emacs Lisp bytecode isn't a low-level sequence of octets (bytes) that requires a lot of additional special-purpose machinery to run. There is however custom C code interpreter to handle each of the instruction primitives, and that is basically it. And even here, many of the instructions are simply a bytecode form of some existing Emacs primitive function like "car" or "point".

Emacs Lisp bytecode is a built-in Emacs Lisp type (same as a say a Lisp "cons" node, or a Lisp symbol).

Functions `aref` and `mapcar` can be used extract the components of bytecode once it is built, the bytecode object is made up of other normal Emacs Lisp objects described next. Byte code is created using the `make-byte-code` function.

One important component of the bytecode object is the "constants vector." It contains important Lisp Objects that are required to make sense of the bytecode-instruction operands: functions that share the same bytecode-instruction byte string, but differ in their constants vectors, can do very different things.

An Emacs Lisp object of a byte code type is analogous to an Emacs Lisp vector. As with a vector, elements are accessed in constant time.

The print syntax of this type is similar to vector syntax, except `#[...]` is displayed to display a bytecode literal instead of `([...]` as is used in a vector.

In contrast to vector object, there are no functions to index or extract parts of a code object once it is build, and a byte-code object can be evaluated as a function. Valid byte-code objects have 4 to 6 elements and each element has a particular structure elaborated on below.

There are two ways to create a byte-code object: using a byte-code object literal or with `make-byte-code` (see Section 2.6.10 [make-byte-code], page 17). Like vector literals, byte-code functions don't need to be quoted.

The elements of a bytecode function literal are:

1. Function Parameter (lambda) List
2. Byte-code Unibyte String
3. Constants Vector
4. Maximum Stack Usage
5. Docstring
6. "Interactive" Specification

2.1.1 Function Parameter (lambda) List

The first element of a bytecode-function literal is the parameter list for the `lambda`. The object takes on two different forms depending on whether the function is lexically or dynamically scoped. If the function is dynamically scoped, the argument list is a list and is exactly what appears in Lisp code. In this case, the arguments will be dynamically bound befor executing the byte code.

Example showing how a parameter list is transformed:

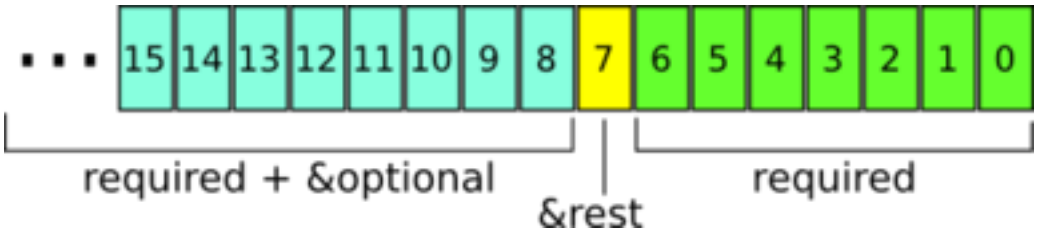
```
(setq lexical-binding nil) ; force lexical binding
(byte-compile
  (lambda (a b &optional c) 5))
;; => #[(a b &optional c) "\300\207" [5] 1]
```

Above we show raw bytecode data. in Emacs after versions after 25 efforts have been made to hide the data.

There's really no shorter way to represent the parameter list because preserving the argument names is critical. Remember that, in dynamic scope, while the function body is being evaluated these variables are globally bound (eww!) to the function's arguments.

On the other hand, when the function is lexically scoped, the parameter list is packed into an Emacs Lisp integer, indicating the counts of the different kinds of parameters: required, `&optional`, and `&rest`. No variable names are needed. Here in contrast to dynamically bound variables, the arguments are onth the stack of the byte-code interperter before executing the code

The following shows how parameter counts and flags are encoded:



The least significant 7 bits indicate the number of required arguments. Notice that this limits compiled, lexically-scoped functions to 127 required arguments. The 8th bit is the number of **&rest** arguments (up to 1). The remaining bits indicate the total number of optional and required arguments (not counting **&rest**). It's really easy to parse these in your head when viewed as hexadecimal because each portion almost always fits inside its own "digit."

Example showing how lexical parameters are encoded:

```
(byte-compile-make-args-desc '())
;; => #x000  (0 args, 0 rest, 0 required)

(byte-compile-make-args-desc '(a b))
;; => #x202  (2 args, 0 rest, 2 required)

(byte-compile-make-args-desc '(a b &optional c))
;; => #x302  (3 args, 0 rest, 2 required)

(byte-compile-make-args-desc '(a b &optional c &rest d))
;; => #x382  (3 args, 1 rest, 2 required)
```

The names of the arguments don't matter in lexical scope: they're purely positional. This tighter argument specification is one of the reasons lexical scope is sometimes faster: the byte-code interpreter doesn't need to parse the entire lambda list and assign all of the

variables on each function invocation; furthermore, variable access is via a compact index located usually in the operand value rather than an index into the constants vector followed by a lookup of the variable.

2.1.2 Byte-code Unibyte String

The second element of a bytecode-function literal is a unibyte string — it strictly holds octets and is not to be interpreted as any sort of Unicode encoding. These strings should be created with unibyte-string because string may return a multibyte string. To disambiguate the string type to the lisp reader when higher values are present (> 127), the strings are printed in an escaped octal notation, keeping the string literal inside the ASCII character set.

Example of a unibyte string:

```
(unibyte-string 100 200 250)
;; => "d\310\372"
```

It's unusual to see a byte-code string that doesn't end with 135 (#o207, return). Perhaps this should have been implicit? I'll talk more about the byte code below.

2.1.3 Constants Vector

The third object in a bytecode-function literal is a constants vector. It's a normal Emacs Lisp vector and can be created with `(vector ...)` or a vector literal.

In addition to the normal kinds of things one thinks of as constants — numbers, strings, and compositions of these — the constants vector importantly contains symbol constants of those dynamic variables and function names which are referred to by the instructions of the byte-code unibyte string.

The amount of space used by an Emacs byte-code instruction, and the number of ways an operand in an instruction can refer to an Lisp object is rather limited. Most operands are only a few bits in length, some fill an entire byte, and occasionally an operand can be two bytes in length. Given this, you can't have an arbitrary string or structured Lisp object listed directly inside an operand. Instead, operands reference either the constants vector or they index into the evaluation stack itself.

Example showing a constants vector:

```
ELISP> (byte-compile
        (lambda (a b)
         (my-func '("hi" "there") a nil 5)))
#[(a b)
  "\301\302Ᵽ\303\304$\207"
  [a my-func
     ("hi" "there")
     nil 5]
  5]
```

The above assumes that dynamic binding is in effect.

The constants vector in the above example contains 5 elements:

- `a` — the symbol `a` which refers to a variable
- `myfunc` the symbol `myfunc` which likely refers to an external function

- `("hi" "there")` a list constant containing two strings
- `nil` the nil constant
- `5` the integer constant 5

The properties of symbol `a` and symbol `myfunc` are consulted at run time, so as such there is no knowledge in the bytecode representing the fact that `a` is a dynamically-bound parmeter while `my-func` is probably an external function.

If the lambda were a lexically-scoped, the constants vector would not have the variable symbol `a` listed, but instead there would be a stack entry.

Note that although the symbol `b` is a parameter of the lambda, it doesn't appear in the constants vector, since it is not used in the body of the function.

2.1.4 Maximum Stack Usage

The fourth object in a bytecode-function literal is an integer which gives the maximum stack space used by this byte-code. This value can be derived from the byte code itself, but it's pre-computed so that the byte-code interpreter can quickly check for stack overflow. Under-reporting this value is probably another way to crash Emacs.

In our example above, maximum-stack value is five since function `myfunc` is called with four parameters which are pushed onto the stack, and there is an additional stack entry pushed the `myfunc` symbol itself. All of this needs to be in place on the stack just before a `call` instruction runs to perform the `myfunc` call.

2.1.5 Docstring

The fifth object in a bytecode-function literal is simple and completely optional. Depending on how the function was created the docstring is either the docstring, or a cons cell indicating a compiled '.elc' and a position for lazy access. Only one position, the start, is needed because the lisp reader is used to load it and it knows how to recognize the end.

2.1.6 "Interactive" Specification

When there is a sixth field in the bytecode-function the function is a command, i.e an "interative" function. Otherwise the function is not a command. That parameter holds the exactly contents of the argument to `interactive` in the uncompiled function definition. Note that `(interactive)` causes the sixth field to be nil, which is distinct from there not being a sixth feild.

Examples showing the interactive specification:

```
ELISP> (byte-compile
         (lambda (n)
           (interactive "nNumber: ") n))
;; => #[(n) "\010\207" [n] 1 nil "nNumber: "]

ELISP> (byte-compile
         (lambda (n)
          (interactive (list (read))) n))
;; => #[(n) "\010\207" [n] 1 nil (list (read))]
```

The interactive expression usually interpreted, which is fine because, by definition, this code is going to be waiting on user input. However, it slows down keyboard macro playback.

2.2 Byte-Code Compiler

The Byte-Code compiler is an ahead-of-time compiler that accepts Emacs Lisp input and produces bytecode that can be run by Emacs. The compiler itself is written in Emacs Lisp[1], and is a comparatively compact program contained in the files `bytecomp.el` and `byte-opt.el`.

Internally, the compiler first produces an intermediate Lisp structure in LAP code, then performs various optimizations on that, and finally translates the LAP code into bytecode. LAP code is used during compilation, but not kept in memory or used when running bytecode.

It is possible to go back to LAP code from bytecode; this is done in order to inline functions and when bytecode disassembly is requested.

[1] usually, the compiler itself is compiled into bytecode, which avoids overflow problems

2.3 Byte-Code Interpreter

When a function is called and the function is represented as bytecode, control passes to the bytecode interpreter. The interpreter is written in C and is written more for speed than readability.

The bytecode interpreter operates on a single function at a time; for a function call, the bytecode interpreter calls other parts of Emacs, which might call the bytecode interpreter again, recursively. Thus, in contrast to languages like FORTH, there is no code stack per se, just the C stack.

The bytecode interpreter implements a stack machine utilizing a fixed-size evaluation stack, which is usually allocated as a block on the C stack. Instructions can access either this stack or a constants vector, which is produced at compile time and made part of the bytecode object.

The evaluation stack, as well as the constants vector, contains Lisp values, usually 64-bit words containing an integer (Emacs integers are limited to 62 bits on 64-bit machines), symbol index, or a tagged pointer to one of various Emacs structures such as markers, buffers, floating-point numbers, vectors, or cons cells.

Values on the evaluation stack are created at run time; values in the constants vector are created when the byte-compiled file is read and converted into bytecode objects. The underlying bit representation of values in the constants vector can vary between Emacs instances: they are constants in the sense that they do not vary within a single Emacs instance.

Bytecode objects contain a number safely estimating the maximum stack size the evaluation stack can grow to.

2.4 Byte-Code Instructions

The bytecode interpreter, once it has set up the evaluation stack and constants vector, executes the instructions that make up the bytecode byte string: each instruction is between one and three bytes in length, containing an opcode in the first byte and sometimes an eight- or 16-bit integer in the following bytes. Those integers are usually unsigned, and 16-bit integers are stored in little-endian byte order, regardless of whether that is the natural byte order for the machine Emacs runs on.

Some opcodes, allocated in blocks, encode an integer as part of the opcode byte.

Bytecode instructions operate on the evaluation stack: for example, `plus`, the addition function, removes two values from the top of the stack and pushes a single value, the sum of the first two values, back on the stack.

Since the arguments for a function call need to be on the stack before the function can operate on them, bytecode instructions use Reverse Polish Notation: first the arguments are pushed on the stack, then the function or operation is called. For example, the Lisp expression `(+ a b)` turns into this bytecode:

```
PC  Byte  Instruction
 0    8   varref a
 1    9   varref b
 2   92   plus
```

First `a` and `b` are dereferenced and their values pushed onto the evaluation stack; then `plus` is executed, leaving only a single value, the sum of `a` and `b`, on the stack.

2.5 Byte-Code Files

When Emacs is build from source code, there is C code for some primitive or built-in functions. These include Lisp functions like `car`, or primitive Emacs functions like `point`. Other equally important functions are implemented in Emacs Lisp. These are byte compiled and then loaded into Emacs. On many systems there is the ability to dump Emacs in some kind of image format after these basic functions have been loaded. But even if that doesn't happen, a file called `loaddefs.el` is created that contains many of the important basic primitive functions as bytecode.

When you invoke Emacs then, it has a number of functions already loaded and these are either coded in C or have been byte compiled and loaded. Before running a function, Emacs queries the type of code that is associated with the function symbol and calls either its lambda S-expression interpreter or its bytecode interpreter.

When you run `load`, which reads and evaluates Lisp code from a file, at the top-level it doesn't matter whether the file contains bytecode or Emacs Lisp source code. Either way the only thing done is to open the file, and read the contents of the file using the normal Lisp reader. The difference between the two kinds of files is more about convention than it is strictly about the contents of the file.

The difference between a Emacs Lisp bytecode file and a Emacs Lisp source file, then is two things. First the bytecode file will have a comment header in it that starts `;ELC^W^@^@^@` while the source code probably doesn't. (However there's nothing to stop you from adding in that line if you feel like it). In addition to this comment header, a bytecode file will have other meta-comments such as which version of Emacs was used to compile the file and whether optimization was used. In earlier versions, there was information about the program that was used to compile the program was given, like its version number. And the source code path used to be in there as well. (I think these things should still be in there but that's a different story). See Chapter 4 [Instruction Changes Between Emacs Releases], page 143, where we give examples of the headers to show how that has changed.

The second thing that is typically different between source code files and bytecode files is the prevalence of the `byte-code` calls used in the file and with the inclusion of those comes a lack of any `defun`, `defmacro`, or `lambda` calls. But again I suppose there's nothing stopping you from using doing likewise in your source code.

In fact, you can take a file with the `.elc` extension, rename it to have an `.el` extension instead and `load` that. And that will run exactly the same if it had been loaded as a byte code file[1].

Similarly, just as you can concatenate any number of independent Emacs Lisp source code files into one file[2], you can do the same with Emacs Lisp bytecode files.

Of course, there will probably certain programs that are fooled when the extension is changed. In particular, the `byte-recompile-directory` function it will think that the bytecode file doesn't exist because it has the wrong extension. So even though Emacs is permissive about such matters, it is best to stick with the normal Emacs conventions.

---

[1] If you go the other direction and rename a Lisp file as a bytecode file, Emacs will notice the discrepency because at the top of the file is a header that Emacs checks. But if you add a reasonable-looking header you can go that direction as well.

[2] and this is sometimes done as a poor-man's way to create a package

The final thing that should be mentioned when talking about bytecode files is interoperability between Emacs versions.

Even though a bytecode header has a meta comment indicating the version of Emacs that was used to compile it, that information is not used in determining whether the bytecode file can be run or not.

This has the benefit of being able to run bytecode compiled in different Emacs version than the version you are currently running. Since Emacs bytecode instructions do not change that often, this largely works. The scary part though is that opcode meanings have changed over the 30 years, and the interpreter is and has been sometimes lacking in checks. (In the past the interpreter has aborted when running an invalid bytecode). So Emacs doesn't even know that you are running bytecode from a different interpreter. There is no check that you aren't going off a cliff running older or newer bytecode.

However, Emacs developer(s) maintain that in practice problems haven't occurred with such frequency that it has been reported happened enough to be a problem. Also, they try to keep backward compatability between versions. In other words, bytecode that was generated in an older version of Emacs but is no longer generated will often still be interpreted in the new version of Emacs. While this is a nice intention, the facts seem to suggest that this isn't always the case. (Nor could it be in reality for a program that is 30 years old or so).

See Chapter 4 [Instruction Changes Between Emacs Releases], page 143, then for when this is likely to work and in what cases it won't. And although running newer bytecode in an older version of Emacs isn't explicitly considered, again, since bytecode doesn't change that often, in reality this too can sometimes work out.

Note that this is in sharp contrast other bytecode interpreters like Python where the magic used in compiling has to be the same as the value of running interpreter or Python will refuse to run.

Personally, I think it would be nice to have a Emacs Lisp bytecode checker, perhaps a `safer-load` function that does look at the bytecode and its meta-comments gleans when there is something that is known to cause problems. Any volunteers?

2.6 Functions and Commands for working with Byte Code

You can byte-compile an individual function or macro definition with the `byte-compile` function. You can compile a whole file with `byte-compile-file`, or several files with `byte-recompile-directory` or `batch-byte-compile`.

Sometimes, the byte compiler produces warning and/or error messages (see Section "Compiler Errors" in *GNU Emacs Lisp Reference Manual*, for details). These messages are normally recorded in a buffer called `*Compile-Log*`, which uses Compilation mode. See Section "Compilation Mode" in *The GNU Emacs Manual*. However, if the variable `byte-compile-debug` is non-nil, error message will be signaled as Lisp errors instead (see Section "Errors" in *GNU Emacs Lisp Reference Manual*).

Be careful when writing macro calls in files that you intend to byte-compile. Since macro calls are expanded when they are compiled, the macros need to be loaded into Emacs or the byte compiler will not do the right thing. The usual way to handle this is with `require` forms which specify the files containing the needed macro definitions (see Section "Named Features" in *GNU Emacs Lisp Reference Manual*). Normally, the byte compiler does not evaluate the code that it is compiling, but it handles `require` forms specially, by loading the specified libraries. To avoid loading the macro definition files when someone *runs* the compiled program, write `eval-when-compile` around the `require` calls (see Section "Eval During Compile" in *GNU Emacs Lisp Reference Manual*). For more details, See Section "Compiling Macros" in *GNU Emacs Lisp Reference Manual*.

Inline (`defsubst`) functions are less troublesome; if you compile a call to such a function before its definition is known, the call will still work right, it will just run slower.

2.6.1 `batch-byte-compile`

`batch-byte-compile` **&optional** *noforce* [Function]

This function runs `byte-compile-file` on files specified on the command line. This function must be used only in a batch execution of Emacs, as it kills Emacs on completion. An error in one file does not prevent processing of subsequent files, but no output file will be generated for it, and the Emacs process will terminate with a nonzero status code.

If *noforce* is non-`nil`, this function does not recompile files that have an up-to-date '`.elc`' file.

```
$ emacs -batch -f batch-byte-compile *.el
```

2.6.2 `batch-byte-recompile-directory`

`batch-byte-recompile-directory` *directory* **&optional** *arg* [Function]

Run `byte-recompile-directory` on the dirs remaining on the command line. Must be used only with `-batch`, and kills Emacs on completion. For example, invoke `emacs -batch -f batch-byte-recompile-directory .`.

Optional argument *arg* is passed as second argument *arg* to `byte-recompile-directory`; see there for its possible values and corresponding effects.

2.6.3 byte-compile

`byte-compile` *form* [Command]

If *form* is a symbol, byte-compile its function definition.

```
(defun factorial (integer)
  "Compute factorial of INTEGER."
  (if (= 1 integer) 1
    (* integer (factorial (1- integer)))))
⇒ factorial

(byte-compile 'factorial)
⇒
#[(integer)
  "^H\301U\203^H^@\301\207\302^H\303^HS!\"\207"
  [integer 1 * factorial]
  4 "Compute factorial of INTEGER."]
```

If *form* is a lambda or a macro, byte-compile it as a function.

```
(byte-compile
  (lambda (a) (* a a)))
⇒
  #[(a) "^H\211\207" [a] 2]
```

If *symbol*'s definition is a byte-code function object, `byte-compile` does nothing and returns `nil`. It does not compile the symbol's definition again, since the original (non-compiled) code has already been replaced in the symbol's function cell by the byte-compiled code.

2.6.4 byte-compile-file

`byte-compile-file` *filename* **&optional** *load* [Command]

This function compiles a file of Lisp code named *filename* into a file of byte-code. The output file's name is made by changing the '`.el`' suffix into '`.elc`'; if *filename* does not end in '`.el`', it adds '`.elc`' to the end of *filename*.

Compilation works by reading the input file one form at a time. If it is a definition of a function or macro, the compiled function or macro definition is written out. Other forms are batched together, then each batch is compiled, and written so that its compiled code will be executed when the file is read. All comments are discarded when the input file is read.

This command returns `t` if there were no errors and `nil` otherwise. When called interactively, it prompts for the file name.

If *load* is non-`nil`, this command loads the compiled file after compiling it. Interactively, *load* is the prefix argument.

```
$ ls -l push*
-rw-r--r-- 1 lewis lewis 791 Oct  5 20:31 push.el

(byte-compile-file "~/emacs/push.el")
     ⇒ t
```

```
$ ls -l push*
-rw-r--r-- 1 lewis lewis 791 Oct  5 20:31 push.el
-rw-rw-rw- 1 lewis lewis 638 Oct  8 20:25 push.elc
```

2.6.5 byte-recompile-directory

`byte-recompile-directory` *directory* **&optional** *flag force* [Command]

This command recompiles every '`.el`' file in *directory* (or its subdirectories) that needs recompilation. A file needs recompilation if a '`.elc`' file exists but is older than the '`.el`' file.

When a '`.el`' file has no corresponding '`.elc`' file, *flag* says what to do. If it is `nil`, this command ignores these files. If *flag* is 0, it compiles them. If it is neither `nil` nor 0, it asks the user whether to compile each such file, and asks about each subdirectory as well.

Interactively, `byte-recompile-directory` prompts for *directory* and *flag* is the prefix argument.

If *force* is non-`nil`, this command recompiles every '`.el`' file that has a '`.elc`' file.

The returned value is unpredictable.

2.6.6 byte-recompile-file

`byte-recompile-file` *filename* **&optional** *force arg load* [Command]

Recompile *filename* file if it needs recompilation. This happens when its '`.elc`' file is older than itself.

If the '`.elc`' file exists and is up-to-date, normally this function *does not* compile *filename*. If the prefix argument *force* is non-nil, however, it compiles *filename* even if the destination already exists and is up-to-date.

If the '`.elc`' file does not exist, normally this function *does not* compile *filename*. If optional argument ARG is 0, it compiles the input file even if the '`.elc`' file does not exist. Any other non-nil value of *arg* means to ask the user.

If optional argument *load* is non-nil, loads the file after compiling.

If compilation is needed, this functions returns the result of `byte-compile-file`; otherwise it returns *no-byte-compile*.

2.6.7 compile-defun

`compile-defun` **&optional** *arg* [Command]

This command reads the defun containing point, compiles it, and evaluates the result. If you use this on a defun that is actually a function definition, the effect is to install a compiled version of that function.

`compile-defun` normally displays the result of evaluation in the echo area, but if *arg* is non-`nil`, it inserts the result in the current buffer after the form it compiled.

2.6.8 `disassemble`

`disassemble` *object* **&optional** *buffer-or-name* [Command]

This command displays the disassembled code for *object*. In interactive use, or if *buffer-or-name* is `nil` or omitted, the output goes in a buffer named `*Disassemble*`. If *buffer-or-name* is non-`nil`, it must be a buffer or the name of an existing buffer. Then the output goes there, at point, and point is left before the output.

The argument *object* can be a function name, a lambda expression, or a byte-code object (see Section 2.1 [Byte-Code Objects], page 5). If it is a lambda expression, `disassemble` compiles it and disassembles the resulting compiled code.

There are a couple of variables that control how disassembly is displayed:

Variable Name	**Default Value**
`disassemble-column-1-indent`	8
`disassemble-column-2-indent`	10
`disassemble-recursive-indent`	3

2.6.9 `display-call-tree`

Even though this is a command, it only has an effect when *byte-compile-generate-call-tree* is set to non-nil; it is `nil` by default. In this case, it is called when a file is byte compiled, such as from `byte-compile-file`.

`display-call-tree` **&optional** *filename* [Command]

Display a call graph of a specified file. This lists which functions have been called, what functions called them, and what functions they call. The list includes all functions whose definitions have been compiled in this Emacs session, as well as all functions called by those functions.

The call graph does not include macros, inline functions, or primitives that the byte-code interpreter knows about directly, e.g. `eq`, `cons`.

The call tree also lists those functions which are not known to be called (that is, to which no calls have been compiled), and which cannot be invoked interactively.

2.6.10 `make-byte-code`

`make-byte-code` *arglist byte-code constants depth* **&optional** *docstring interactive-spec* **&rest** *elements* [Function]

Create a byte-code object with specified arguments as elements. The arguments should be the *arglist*, bytecode-string *byte-code*, constant vector *constants*, maximum stack size *depth*, (optional) *docstring*, and (optional) *interactive-spec*.

We briefly describe parameters below. For a more detailed discussion of the parameters, see Section 2.1 [Byte-Code Objects], page 5.

The first four arguments are required; at most six have any significance. The *arglist* can be either like the one of lambda, in which case the arguments will be dynamically bound before executing the byte code, or it can be an integer of the form *NNNNNNNRMMMMMMM* where the 7bit *MMMMMMM* specifies the minimum

number of arguments, the 7-bit *NNNNNNN* specifies the maximum number of arguments (ignoring **&rest**) and the *R* bit specifies whether there is a **&rest** argument to catch the left-over arguments. If such an integer is used, the arguments will not be dynamically bound but will be instead pushed on the stack before executing the byte-code.

There very little checking of the validity of the elements either at creation time or at run time. If a parameter is are invalid or inconsistent, Emacs may crash when you call the function.

Examples of calling `make-byte-code`:

```
;; Null bytecode: no args, no bytecode, no stack needed
(make-byte-code nil "" [] 0)
=>
#[nil ""
    []
    0]

;; This byte-code for: '(lambda(a) (* a a ))
(make-byte-code '(a) "^H211_\207" [a] 2)
=>
#[(a)
  "^H211_\207"
  [a]
  2]

(make-byte-code 1 2 3 4)
=> #[1 2 3 4]
;; Doesn't even do type checking!
```

2.7 Byte-Code Optimization

This is taken more or less from `bytecomp.el` *comments.*

- optimization of compiled code:
  - removal of unreachable code;
  - removal of calls to side-effectless functions whose return-value is unused;
  - compile-time evaluation of safe constant forms, such as (`consp`, `nil`, and `(ash 1 6)`
  - open-coding of literal lambdas;
  - peephole optimization of emitted code;
  - trivial functions are left uncompiled for speed.
- support for inline functions;
- compile-time evaluation of arbitrary expressions;
- compile-time warning messages for:
  - functions being redefined with incompatible arglists;
  - functions being redefined as macros, or vice-versa;
  - functions or macros defined multiple times in the same file;
  - functions being called with the incorrect number of arguments;
  - functions being called which are not defined globally, in the file, or as autoloads;
  - assignment and reference of undeclared free variables;
  - various syntax errors;
- correct compilation of nested `defuns`, `defmacros`, `defvars` and `defsubsts`;
- correct compilation of top-level uses of macros;
- the ability to generate a histogram of functions called.

3 Emacs Lisp Byte-Code Instructions

3.1 Instruction-Description Format

In this chapter we'll document instructions over the course of the entire history of Emacs. Or at least we aim to.

For the opcode names, we will prefer canonicalized names from the Emacs C source `bytecode.c` (under directory `src/`) when those differ from the names in `bytecomp.el` (under directory `lisp/emacs-lisp`). Most of the time they are the same under the transformation described below.

We use names from `bytecode.c` because that is a larger set of instruction names. Specifically, obsolete instructions names (both those that can be interpreted even though they are no longer generated, and some that are no longer interpreted) are defined in that file, whereas that is not the case in `bytecomp.el`.

Names in `bytecode.c` must follow C conventions and must be adjusted to harmonize with other C names used. But this aspect isn't of use here, so we canonicalize those aspects away.

For example, in `bytecode.c` there is an opcode whose name is `Bbuffer_substring`. We will drop the initial `B` and replace all underscores (`_`) with dashes (`-`). Therefore we use `buffer-substring`.

The corresponding name for that opcode in `bytecomp.el` is `byte-buffer-substring`. For the most part, if you drop the initial `byte-` prefix in the `bytecomp.el` name you will often get the canonic name from `bytecode.c`.

However this isn't always true. The instruction that the Emacs Lisp `save-current-buffer` function generates nowadays has opcode value 114. In the C code, this value is listed as `B_save_current_buffer_1`; `bytecomp.el` uses the name `byte-save-current-buffer`. We report the instruction name for opcode 114 as `save-current-buffer-1`.

To shorten and regularize instruction descriptions, each instruction is described a standard format. We will also require a small amount of jargon. This jargon are explained below.

3.1.1 Instruction Jargon

- `TOS` The value of top of the evaluation stack. Many instructions either read or push onto this.
- `S` This is an array of evaluation stack items. `S[0]` is the top of the stack, or `TOS`.
- `top` A pointer to the the top of the evaluation stack. In C this would be `&TOS`. When we want the stack to increase in size, we add to top. For example, to makes space to store a new single new value, we can use `top++` and then assign to `TOS`.

  Note that in changing `top`, the value accessed by `TOS` or `S` values all change.
- ϕ This is used in describing stack effects for branching instructions where the stack effect is different on one branch versus the other. This is a function of two arguments. The first argument gives the stack effect on the non-nil branch and the second argument gives the stack effect for the nil branch. So $\phi(0, -1)$ which is seen in `goto-if-not-nil-else-pop` means that if the jump is taken, the stack effect is 0, otherwise the effect removes or pops an evaluation-stack entry.

- instruction-name subscripting (`[]`) In many instructions such as `constant`, `varref`, you will find an index after the instruction name. What's going on is that instruction name is one of a number of opcodes in a class encodes an index into the instruction. We generally call this an "Argument-encoding" instruction. In the display of the opcode in assembly listings and in the opcode table chapter where we list each opcode, we will include that particular instruction variant in subscripts.

  For example consider `constant[0]` versus `constant[1]`. The former has opcode 192 while the latter has opcode 193. In terms of semantics, the former is the first or zeroth-index entry in a function's constant vector while the latter is the second or 1-index entry.

3.1.2 Instruction Description Fields

The description of fields use for describing each instruction is as follows

Implements:
A description of what the instruction does.

Generated via:
These give some Emacs Lisp constructs that may generate the instruction. Of course there may be many constructs and there may be limiting situations within that construct. We'll only give one or a few of the constructs, and we'll try to indicate a limiting condition where possible.

Operand: When an instruction has an operand, this descripts the type of the operand. Note that the size of the operand (or in some cases the operand value) will determine the instruction size.

Instruction size:
The number of bytes in the instruction. This is 1 to 3 bytes.

Stack effect:
This describes how many stack entries are read and popped and how many entries stack entries are pushed. Although this is logically a tuple, we'll list this a tuple like $(-3, 2)$ as a single scalar $-3 + 2$. In this example, we read/remove three stack entries and add two. The reason we give this as $-3 + 2$ rather than the tuple format is so that the overall effect (removing a stack entry) can be seen by evaluating the expression.

Added in: This is optional. When it is given this gives which version of Emacs the opcode was added. It may also give when the opcode became obsolete or was no longer implemented.

Example: Some Emacs Lisp code to show how the instruction is used. For example the for the `goto` instruction we give:

```
(defun goto-eg(n)
  (while (n) 1300))
```

generates:

```
PC  Byte  Instruction
 0  192   constant[0] n
 1   32   call[0]
```

```
 2  133   goto-if-nil-else-pop [8]
           8
           0
 5  130   goto [0]
           0
           0
 8  135   return

Constants Vector: [n]
```

From the above we see that the `goto` instruction at program counter (PC) 5, has decimal opcode 130. The instruction is three bytes long: a one-byte opcode followed by a two-byte operand.

The instruction name at PC 0 with opcode 192, `constant[0]`, looks like it is indexing, but it is a just name, where the brackets and number are part of the name. We use this kind of name because it is suggestive of how it works: it indexes the first element into the constants vector and pushes that value onto the evaluation stack. `constant[1]` with opcode 193 pushes the second element of the constants vector onto the stack. We could have also used instruction names like `constant0` and `constant1` for opcodes 192 and 193 instead.

Unless otherwise stated, all code examples were compiled in Emacs 25 with optimization turned off.

3.2 Argument-Packing Instructions

These instructions from opcode 1 to 47 encode an operand value from 0 to 7 encoded into the first byte. If the encoded value is 6, the actual operand value is the byte following the opcode. If the encoded value is 7, the actual operand value is the two-byte number following the opcode, in Little-Endian byte order.

`stack-ref` (1–7)

Reference a value from the evaluation stack.

Implements:
`top++; TOS <- S[i+1]` where `i` is the value of the instruction operand.

Generated via:
`let`, `let*` and lambda arguments.

Operand: A stack index

Instruction size:
1 byte for `stack-ref[0]` .. `stack-ref[4]`; 2 bytes for `stack-ref[5]`, 8-bit operand; 3 bytes for `stack-ref[6]`, 16-bit operand.

Stack effect:
$-0+1$.

Added in: Emacs 24.1. See Section 4.7 [Emacs 24], page 148.

Example: When lexical binding and optimization are in effect,

```
(defun stack-ref-eg()
  (let ((a 5) (_b 6) (c 7))
    (+ a c)))}
```

generates:

```
PC  Byte  Instruction
 0  192   constant[0] 5 ;; top++; TOS <- 5
 1  193   constant[1] 6 ;; top++; TOS <- 6
 2  194   constant[2] 7 ;; top++; TOS <- 7
 3    2   stack-ref[2]  ;; top++; TOS <- S[3] (5)
 4    1   stack-ref[1]  ;; top++; TOS <- S[2] (7)
 5   92   plus
 6  135   return

Constants Vector: [5 6 7]
```

Warning Running an instruction with opcode 0 (logically this would be called `stack-ref[0]`), will cause an immediate abort of Emacs in versions after version 20 and before version 25! The abort of the opcode was in place before this instruction was added.

Zero is typically an invalid in bytecode and in machine code, since zero values are commonly found data, e.g. the end of C strings, or data that has been initialized to value but represents data that hasn't been written to yet. By having it be an invalid instruction, it is more likely to catch situations where random sections of memory are run such as by setting the PC incorrectly.

varref (8–15)

varref (8–15)

Pushes the value of the symbol in the constants vector onto the evaluation stack.

Implements:

`top++; TOS <- (eval constants_vector[i])` where `i` is the value of instruction operand

Generated via:

dynamic variable access

Operand: A constants vector index. The constants vector item should be a variable symbol.

Instruction size:

1 byte for `varref[0]` .. `varref[4]`; 2 bytes for `varref[5]`, 8-bit operand; 3 bytes for `varref[6]`, 16-bit operand.

Stack effect:

$-0+1$.

Example: When dynamic binding is in effect,

```
(defun varref-eg(n)
  n)
```

generates:

```
PC  Byte  Instruction
 0    8   varref[0] n
 1  135   return

Constants Vector: [n]
```

varset (16–23)

varset (16–23)

Sets a variable listed in the constants vector to the TOS value of the stack.

Implements:

`constants_vector[i] <- TOS; top--` where `i` is the value of the instruction operand.

Operand: A constants vector index. The constants vector item should be a variable symbol.

Instruction size:

1 byte for `varset[0]` .. `varset[4]`; 2 bytes for `varset[5]`, 8-bit operand; 3 bytes for `varset[6]`, 16-bit operand.

Stack effect:

$-0+1$.

Example: When dynamic binding is in effect,

```
defun varset-eg(n)
  (setq n 5))
```

generates:

```
PC  Byte  Instruction
 0  193   constant[1] 5
 1  137   dup
 2   16   varset[0] n ;; sets variable n
 3  135   return

Constants Vector: [n 5]
```

varbind (24–31)

`varbind` (24–31)

Binds a variable to a symbol in the constants vector, and adds the symbol to a special-bindings stack.

Implements:

`(set_internal(constants_vector[i])` where `i` is the value of the instruction operand.

Instruction size:

1 byte for `varbind[0]` .. `varbind[4]`; 2 bytes for `varbind[5]`, 8-bit operand; 3 bytes for `varbind[6]`, 16-bit operand.

Stack effect:

$-0+1$.

Example: When dynamic binding is in effect,

```
defun varbind-eg()
  (let ((c 1))
    (1+ c)))
```

generates:

```
PC  Byte  Instruction
 0  193   constant[1] 1
 1  137   dup
 2   24   varbind[0] c ;; creates variable c
 3   84   add1
 4   41   unbind[1]    ;; removes variable c
 5  135   return

Constants Vector: [c 1]
```

call (32–39)

`call` (32–39)

Calls a function. The instruction argument specifies the number of arguments to pass to the function from the stack, excluding the function itself.

Implements:

`(set_internal(constants_vector[i])` where `i` is the value of the instruction operand.

Instruction size:

1 byte for `call[0]` .. `call[4]`; 2 bytes for `call[5]`, 8-bit operand; 3 bytes for `call[6]`, 16-bit operand.

Stack effect:

$-0+1$.

Example:

```
(defun call-eg()
  (exchange-point-and-mark)
  (next-line 2))
```

generates:

```
PC  Byte  Instruction
 0  192   constant[0] exchange-point-and-mark
 1   32   call[0]
 2  136   discard
 3  193   constant[1] next-line
 4  194   constant[2] 2
 5   33   call[1]
 6  135   return

Constants Vector: [exchange-point-and-mark next-line 2]
```

unbind (40–47)

unbind (40–47)

Remove the binding of a variable to symbol and from the special stack. This is done when the variable is no longer needed.

Implements:
undo's a `let`, `unwind-protects`, and `save-excursions`

Generated via:
`let` in dynamic binding. Balancing the end of `save-excursion`.

Instruction size:
1 byte for `unbind[0]` .. `unbind[4]`; 2 bytes for `unbind[5]`, 8-bit operand; 3 bytes for `unbind[6]`, 16-bit operand.

Stack effect:
$-0+0$.

Example: When dynamic binding is in effect,

```
defun varbind-eg()
  (let ((c 1))
    (1+ c)))
```

generates:

```
PC  Byte  Instruction
 0  193   constant[1] 1
 1  137   dup
 2   24   varbind[0] c ;; creates variable c
 3   84   add1
 4   41   unbind[1]    ;; removes variable c
 5  135   return

Constants Vector: [c 1]
```

3.3 Constants-Vector Retrieval Instructions

The instructions from opcode 192 to 255 push a value from the Constants Vector. See Section 2.1.3 [Constants Vector], page 7. Opcode 192 pushes the first entry, opcode 193, the second and so on. If there are more than 64 constants, opcode `constant2` (opcode 129) is used instead.

`constant` (192–255)

Pushes a value from the constants vector on the evaluation stack. There are special instructions to push any one of the first 64 entries in the constants stack.

Implements:

`top++; TOS <- constants_vector[i]` where `i` is the value of the instruction operand.

Instruction size:

1 byte

Stack effect:

$-0+1$.

Example:

```
defun n3(n)
  (+ n 10 11 12))
```

generates:

```
PC  Byte  Instruction
 0  193   constant[1] +
 1    8   varref[0] n
 2  194   constant[2] 10
 3  195   constant[3] 11
 4  196   constant[4] 12
 5   36   call[4]
 6  135   return

Constants Vector: [n + 10 11 12]
```

constant2 (129)

`constant2` (129)

Pushes a value from the constants vector on the evaluation stack. Although there are special instructions to push any one of the first 64 entries in the constants stack, this instruction is needed to push a value beyond one the first 64 entries.

Implements:

`top++; TOS <- constants_vector[i]` where `i` is the value of the instruction operand.

Operand: a 16-bit index into the constants vector.

Instruction size:

3 bytes

Stack effect:

$-0+1$.

Example:

```
(defun n64(n)
 (+ n 0 1 2 3 .. 64))
```

generates:

```
PC  Byte  Instruction
 0  193   constant[1] +
 1    8   varref[0] n
 2  194   constant[2] 0
 3  195   constant[3] 1
 4  196   constant[4] 2
[...]
63  255   constant[63] 61
64  129   constant2 [64] 62
          64
           0
67  129   constant2 [65] 63
          65
           0
70  129   constant2 [66] 64
          66
           0
73   38   call [66]
          66
75  135   return

Constants Vector: [n + 0 1 2 .. 61 62 63 64]
```

3.4 Exception-Handling Instructions

`pophandler` (48)

Implements:
Removes last condition pushed by `pushconditioncase`

Generated via:
`condition-case`

Instruction size:
1 byte

Stack effect:
$-0+0$.

Added in: Emacs 24.4. See Section 4.7 [Emacs 24], page 148.

Example:

```
(defun pushconditioncase-eg()
  (condition-case nil
    5
    (one-error 6)
    (another-error 7)))
```

generates:

```
PC  Byte  Instruction
 0  192   constant[0] (another-error)
 1   49   pushconditioncase [16]
          16
           0
 4  193   constant[1] (one-error)
 5   49   pushconditioncase [12]
          12
           0
 8  194   constant[2] 5
 9   48   pophandler
10   48   pophandler
11  135   return
12   48   pophandler
13  136   discard
14  195   constant[3] 6
15  135   return
16  136   discard
17  196   constant[4] 7
18  135   return

Constants Vector: [(another-error) (one-error) 5 6 7]
```

pushconditioncase (49)

pushconditioncase (49)

Implements:

Pops the TOS which is some sort of condition to test on and registers that. If any of the instructions errors with that condition, a jump to the operand occurs.

Operand: 16-bit PC address

Instruction size:

3 bytes

Stack effect:

$-1 + 0$.

Added in: Emacs 24.4. See Section 4.7 [Emacs 24], page 148.

Example:

```
(defun pushconditioncase-eg()
  (condition-case nil
    5
    (one-error 6)
    (another-error 7)))
```

generates:

```
PC  Byte  Instruction
 0  192   constant[0] (another-error)
 1   49   pushconditioncase [16]
          16
           0
 4  193   constant[1] (one-error)
 5   49   pushconditioncase [12]
          12
           0
 8  194   constant[2] 5
 9   48   pophandler
10   48   pophandler
11  135   return
12   48   pophandler
13  136   discard
14  195   constant[3] 6
15  135   return
16  136   discard
17  196   constant[4] 7
18  135   return

Constants Vector: [(another-error) (one-error) 5 6 7]
```

pushcatch (50)

pushcatch (50)
?

3.5 Control-Flow Instructions

`goto` (130)

Implements:
Jump to label given in the 16-bit operand

Generated via:
`while` and various control-flow constructs

Operand: 16-bit PC address

Instruction size:
3 bytes

Stack effect:
$-0+0$

Example: `(defun goto-eg(n) (while (n) 1300))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] n
 1   32   call[0]
 2  133   goto-if-nil-else-pop [8]
           8
           0
 5  130   goto [0]
           0
           0
 8  135   return

Constants Vector: [n]
```

goto-if-nil (131)

`goto-if-nil` (131)

Implements:
Jump to label given in the 16-bit operand if TOS is nil. In contrast to `goto-if-nil-else-pop`, the test expression, TOS, is always popped.

Generated via:
`if` with "else" clause and various control-flow constructs

Operand: 16-bit PC address

Instruction size:
3 bytes

Stack effect:
$-1+0$

Example: `(defun goto-if-nil-eg(n) (if (n) 1310 1311))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] n
 1   32   call[0]
 2  131   goto-if-nil [9]
           9
           0
 5  193   constant[1] 1310
 6  130   goto [10]
           10
           0
 9  194   constant[2] 1311
10  135   return

Constants Vector: [n 1310 1311]
```

goto-if-not-nil (132)

`goto-if-not-nil` (132)

Implements:

Jump to label given in the 16-bit operand if TOS is not nil. In contrast to `goto-if-not-nil-else-pop`, the test expression, TOS, is always popped.

Generated via:

`or` inside an `if` with optimization and various control-flow constructs

Operand: 16-bit PC address

Instruction size:

3 bytes

Stack effect:

$-1+0$

Example: With bytecode optimization, `(defun goto-if-not-nil-eg(n) (if (or (n) (n)) 1320))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] n
 1   32   call[0]
 2  132   goto-if-not-nil [10]
           10
            0
 5  192   constant[0] n
 6   32   call[0]
 7  133   goto-if-nil-else-pop [11]
           11
            0
10  193   constant[1] 1320
11  135   return

Constants Vector: [n 1320]
```

Note the change in opcode when bytecode optimization is not performed.

goto-if-nil-else-pop (133)

`goto-if-nil-else-pop` (133)

Implements:

Jump to label given in the 16-bit operand if TOS is nil; otherwise pop the TOS, the tested condition. This allows the test expression, nil, to be used again on the branch as the TOS.

Generated via:

`cond`, `if` and various control-flow constructs

Operand: 16-bit PC address

Instruction size:

3 bytes

Stack effect:

$\phi(0, -1) + 0$

Example: `(defun goto-if-nil-else-pop-eg(n) (cond ((n) 1330)))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] n
 1   32   call[0]
 2  133   goto-if-nil-else-pop [6]
           6
           0
 5  193   constant[1] 1330
 6  135   return

Constants Vector: [n 1330]
```

goto-if-not-nil-else-pop (134)

goto-if-not-nil-else-pop (134)

Implements:

Jump to label given in the 16-bit operand if TOS is not nil; otherwise pop TOS, the tested condition. This allows the tested expression on TOS to be used again when the jump is taken.

Generated via:

`cond`, `if` and various control-flow constructs

Operand: 16-bit PC address

Instruction size:

3 bytes

Stack effect:

$\phi(0, -1) + 0$

Example:

```
(defun goto-if-not-nil-else-pop-eg(n)
  (if (or (n) (n))
    1340))
```

generates:

```
PC  Byte  Instruction
 0  192   constant[0] n
 1   32   call[0]
 2  134   goto-if-not-nil-else-pop [7]
           7
           0
 5  192   constant[0] n
 6   32   call[0]
 7  133   goto-if-nil-else-pop [11]
           11
           0
10  193   constant[1] 1340
11  135   return

Constants Vector: [n 1340]
```

Note the change in opcode when bytecode optimization is performed.

return (135)

`return` (135)

Implements:

Return from function. This is the last instruction in a function's bytecode sequence. The top value on the evaluation stack is the return value.

Generated via:

`lambda`

Instruction size:

1 byte

Stack effect:

$-1+0$

Example: `(defun return-eg(n) 1350)` generates:

```
PC  Byte  Instruction
 0  192   constant[0] 1350
 1  135   return

Constants Vector: [1350]
```

switch (183)

`switch` (183)

Jumps to entry in a jumptable.

Implements:

switch-like jumptable. Top of stack is a variable reference. Below that is a hash table mapping compared values to instructions offsets.

Generated via:

`cond` with several clauses that use the same test function and variable.

Instruction size:

1 byte

Stack effect:

$-2 + 0$

Added in: Emacs 26.1

Example:

```
(defun switch-eg(n)
   (cond ((equal n 1) 1)
          ((equal n 2) 2)
          ((equal n 3) 3)))
```

generates:

```
PC  Byte  Instruction
 0    8   varref[0] n
 1  193   constant[1] #s(hash-table size 3 test equal rehash-size 1.5 rehash-thre
 2  183   switch
 3  130   goto [12]
          12
           0
 6  194   constant[2] 1
 7  135   return
 8  195   constant[3] 2
 9  135   return
10  196   constant[4] 3
11  135   return
12  197   constant[5] nil
13  135   return

Constants Vector: [n #s(hash-table size 2 test equal rehash-size 1.5 rehash-thres
```

3.6 Function-Call Instructions

These instructions use up one byte, and are followed by the next instruction directly. They are equivalent to calling an Emacs Lisp function with a fixed number of arguments: the arguments are popped from the stack, and a single return value is pushed back onto the stack.

3.6.1 Lisp Function Instructions

These instructions correspond to general functions which are not specific to Emacs; common cases are usually inlined for speed by the bytecode interpreter.

`symbolp` (57)

Call `symbolp`.

Implements:
`TOS <- (symbolp TOS)`.

Generated via:
`symbolp`.

Instruction size:
1 byte

Stack effect:
$-1+1$.

Example: When lexical binding is in effect, `(defun symbolp-eg(n) (symbolp n))` generates:

```
PC  Byte  Instruction
 0  137   dup
 1   57   symbolp
 2  135   return
```

consp (58)

consp (58)

Call consp.

Implements:
TOS <- (consp TOS).

Generated via:
consp.

Instruction size:
1 byte

Stack effect:
$-1+1$.

Example: When lexical binding is in effect, (defun consp-eg(n) (consp n)) generates:

```
PC  Byte  Instruction
 0  137   dup
 1   58   consp
 2  135   return
```

stringp (59)

`stringp` (59)

Call `stringp`.

Implements:
`TOS <- (stringp TOS)`.

Generated via:
unary `stringp`.

Instruction size:
1 byte

Stack effect:
$-1+1$.

Example: When lexical binding is in effect, `(defun stringp-eg(n) (stringp n))` generates:

```
PC  Byte  Instruction
 0  137   dup
 1   59   stringp
 2  135   return
```

listp (60)

`listp` (60)

Call `listp`.

Implements:
`TOS <- (listp TOS)`.

Generated via:
unary `listp`.

Instruction size:
1 byte

Stack effect:
$-1+1$.

Example: When lexical binding is in effect, `(defun listp-eg(n) (listp n))` generates:

```
PC  Byte  Instruction
 0  137   dup
 1   60   listp
 2  135   return
```

eq (61)

eq (61)

Call eq.

Implements:
S[1] <- (eq S[1] TOS); top--.

Generated via:
binary eq.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Example: When lexical binding is in effect, (defun eq-eg(a b) (eq a b)) generates:

```
PC  Byte  Instruction
 0    1   stack-ref[1]
 1    1   stack-ref[1]
 2   61   eq
 3  135   return
```

memq (62)

memq (62)

Call memq.

Implements:
S[1] <- (memq S[1] TOS); top--.

Generated via:
binary memq.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Example: When lexical binding is in effect, (defun memq-eg(a b) (memq a b)) generates:

```
PC  Byte  Instruction
 0    1   stack-ref[1]
 1    1   stack-ref[1]
 2   62   memq
 3  135   return
```

not (63)

not (63)

Call not.

Implements:
TOS <- (not TOS).

Generated via:
unary not.

Instruction size:
1 byte

Stack effect:
$-1+1$.

Example: When lexical binding is in effect, (defun not-eg(a) (not a)) generates:

```
PC  Byte  Instruction
 0  137   dup
 1   63   not
 2  135   return
```

symbol-value (74)

`symbol-value` (74)

Call `symbol-value`.

Implements:
`TOS <- (symbol-value TOS)`.

Generated via:
`symbol-value`.

Instruction size:
1 byte

Stack effect:
$-1+1$.

Example: When lexical binding is in effect, `(defun symbol-value-eg(a) (symbol-value a))` generates:

```
PC  Byte  Instruction
 0  137   dup
 1   74   symbol-value
 2  135   return
```

symbol-function (75)

`symbol-function` (75)

Call `symbol-function`.

Implements:
`TOS <- (symbol-function TOS)`.

Generated via:
`symbol-function`.

Instruction size:
1 byte

Stack effect:
$-1+1$.

Example: When lexical binding is in effect, `(defun symbol-function-eg(a) (symbol-function a))` generates:

```
PC  Byte  Instruction
 0  137   dup
 1   75   symbol-function
 2  135   return
```

set (76)

`set` (76)

Call `set`.

Implements:
`S[1] <- (set S[1] TOS); top--`.

Generated via:
`set`.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Example: When lexical binding is in effect, `(defun set-eg(a b) (set a b))` generates:

```
PC  Byte  Instruction
 0    1   stack-ref[1]
 1    1   stack-ref[1]
 2   76   set
 3  135   return
```

fset (77)

`fset` (77)

Call `fset`.

Implements:
`S[1] <- (fset S[1] TOS); top--`.

Generated via:
binary `fset`.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Example: When lexical binding is in effect, `(defun fset-eg(a b) (fset a b))` generates:

```
PC  Byte  Instruction
 0    1   stack-ref[1]
 1    1   stack-ref[1]
 2   77   fset
 3  135   return
```

get (78)

`get` (78)

Call `get`.

Implements:
`S[1] <- (get S[1] TOS); top--`.

Generated via:
binary `get`.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Example: When lexical binding is in effect, `(defun get-eg(a b) (get a b))` generates:

```
PC  Byte  Instruction
 0    1   stack-ref[1]
 1    1   stack-ref[1]
 2   78   get
 3  135   return
```

equal (154)

`equal` (154)

Call `equal`.

Implements:
`S[1] <- (equal S[1] TOS); top--`.

Generated via:
binary `equal`.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: When lexical binding is in effect, `(defun equal-eg(a b) (equal a b))` generates:

```
PC  Byte  Instruction
 0    1   stack-ref[1]
 1    1   stack-ref[1]
 2  154   equal
 3  135   return
```

member (157)

`member` (157)

Call `member`.

Implements:
`S[1] <- (member S[1] TOS); top--`.

Generated via:
`member`.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Example: When lexical binding is in effect, `(defun member-eg(a b) (member a b))` generates:

```
PC  Byte  Instruction
 0    1   stack-ref[1]
 1    1   stack-ref[1]
 2  157   member
 3  135   return
```

assq (158)

assq (158)

Call assq.

Implements:
S[1] <- (assq S[1] TOS); top--.

Generated via:
binary assq.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Example: When lexical binding is in effect, (defun assq-eg(a b) (assq a b)) generates:

```
PC  Byte  Instruction
 0    1   stack-ref[1]
 1    1   stack-ref[1]
 2  158   assq
 3  135   return
```

numberp (167)

numberp (167)

Call `numberp`.

Implements:
`TOS <- (numberp TOS)`.

Generated via:
`numberp`.

Instruction size:
1 byte

Stack effect:
$-1+1$.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: When lexical binding is in effect, `(defun numberp-eg(a) (numberp a))` generates:

```
PC  Byte  Instruction
 0  137   dup
 1  167   numberp
 2  135   return
```

integerp (168)

`integerp` (168)

Call `integerp`.

Implements:
`TOS <- (integerp TOS)`.

Generated via:
`integerp`.

Instruction size:
1 byte

Stack effect:
$-1+1$.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: When lexical binding is in effect, `(defun integerp-eg(a) (integerp a))` generates:

```
PC  Byte  Instruction
 0  137   dup
 1  168   integerp
 2  135   return
```

3.6.2 List Function Instructions

These instructions correspond to general functions which are not specific to Emacs; common cases are usually inlined for speed by the bytecode interpreter.

`nth` (56)

Call `nth` with two stack arguments.

Implements:
`S[1] <- (nth S[1] TOS); top--`.

Generated via:
`nth`.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Example: When lexical binding is in effect, `(defun nth-eg(l) (nth 560 l))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] 560
 1    1   stack-ref[1]
 2   56   nth
 3  135   return

Constants Vector: [560]
```

car (64)

car (64)

Call `car` with one stack argument.

Implements:
`TOS <- (car TOS)`.

Generated via:
`car`.

Instruction size:
1 byte

Stack effect:
$-1+1$.

Example: When lexical binding is in effect, `(defun car-eg(l) (car l))` generates:

```
PC  Byte  Instruction
 0  137   dup
 1   64   car
 2  135   return
```

cdr (65)

`cdr` (65)

Call `cdr` with one stack argument.

Implements:
`TOS <- (cdr TOS)`.

Generated via:
`cdr`.

Instruction size:
1 byte

Stack effect:
$-1+1$.

Example: When lexical binding is in effect, `(defun cdr-eg(l) (cdr l))` generates:

```
PC  Byte  Instruction
 0  137   dup
 1   65   cdr
 2  135   return
```

cons (66)

cons (66)

Call cons with two stack arguments.

Implements:
S[1] <- (cons S[1] TOS); top--.

Generated via:
cons.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Example: (defun cons-eg() (cons 'a 'b)) generates:

```
PC  Byte  Instruction
 0  192   constant[0] a
 1  193   constant[1] b
 2   66   cons
 3  135   return

Constants Vector: [a b]
```

list1 (67)

`list1` (67)

Call `list` with TOS.

Implements:
`TOS <- (list TOS)`.

Generated via:
`list`.

Instruction size:
1 byte

Stack effect:
$-1+1$.

Example: `(defun list1-eg() (list 'a))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] a
 1   67   list1
 2  135   return

Constants Vector: [a]
```

Call `list` with TOS.

list2 (68)

`list2` (68)

Call `list` with two stack items.

Implements:
`S[1] <- (list S[1] TOS); top--`.

Generated via:
`list`.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Example: `(defun list2-eg() (list 'a 'b))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] a
 1  193   constant[1] b
 2   68   list2
 3  135   return

Constants Vector: [a b]
```

list3 (69)

`list3` (69)

Call `list` with three stack items.

Implements:

`S[2] <- (list S[2] S[1] TOS); top -= 2`.

Generated via:

`list`

Instruction size:

1 byte

Stack effect:

$-3+1$.

Example: `(defun list3-eg() (list 'a 'b 'c))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] a
 1  193   constant[1] b
 2  194   constant[2] c
 3   69   list3
 4  135   return

Constants Vector: [a b c]
```

list4 (70)

`list4` (70)

Call `list` with four stack items.

Implements:
`S[3] <- (list S[3] S[2] S[1] TOS); top -= 2`.

Generated via:
`list`.

Instruction size:
1 byte

Stack effect:
$-4+1$.

Example: `(defun list4-eg() (list 'a 'b 'c 'd))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] a
 1  193   constant[1] b
 2  194   constant[2] c
 3  195   constant[3] d
 4   70   list4
 5  135   return

Constants Vector: [a b c d]
```

listN (175)

`listN` (175)

Call `list` on up to 255 items. Note that there are special instructions for the case where there are 1 to 4 items in the list.

Implements:
`S[n-1] <- (list S[n-1] S[n-2] ... TOS); top -= (n-1)` where `n` is the value of the operand.

Generated via:
`list`.

Operand: 8-bit number of items in list

Instruction size:
2 bytes

Stack effect:
$-n+1$ where n is the value of the instruction operand.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: `(defun listN-eg() (list 'a 'b 'c 'd 'e))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] a
 1  193   constant[1] b
 2  194   constant[2] c
 3  195   constant[3] d
 4  196   constant[4] e
 5  175   listN [5]
           5
 7  135   return

Constants Vector: [a b c d e]
```

length (71)

`length` (71)

Call `length` with one stack argument.

Implements:
`TOS <- (length TOS)`.

Generated via:
`length`.

Instruction size:
1 byte

Stack effect:
$-1+1$.

Example: `(defun length-eg() (length '(a b)))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] (a b)
 1   71   length
 2  135   return

Constants Vector: [(a b)]
```

aref (72)

aref (72)

Call `aref` with two stack arguments.

Implements:
`S[1] <- (aref S[1] TOS); top--`.

Generated via:
`aref`.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Example: `(defun aref-eg() (aref '[720 721 722] 0))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] [720 721 722]
 1  193   constant[1] 0
 2   72   aref
 3  135   return

Constants Vector: [[720 721 722] 0]
```

aset (73)

aset (73)

Call aset with three stack arguments.

Implements:
S[2] <- (aset S[2] S[1] TOS); top-=2.

Generated via:
aset.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Example: (defun aset-eg() (aset array-var 0 730)) generates:

```
PC  Byte  Instruction
 0    8   varref[0] array-var
 1  193   constant[1] 0
 2  194   constant[2] 730
 3   73   aset
 4  135   return

Constants Vector: [array-var 0 730]
```

nthcdr (155)

`nthcdr` (155)

Call `nthcdr` with two stack arguments.

Implements:
`S[1] <- (nthcdr S[1] TOS); top --`.

Generated via:
`nthcdr`.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: `(defun nthcdr-eg() (nthcdr '(1550 1551 1552) 2))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] (1550 1551 1552)
 1  193   constant[1] 2
 2  155   nthcdr
 3  135   return

Constants Vector: [(1550 1551 1552) 2]
```

elt (156)

`elt` (156)

Call `elt` with two stack arguments.

Implements:
`S[1] <- (elt S[1] TOS); top --`.

Generated via:
`elt`.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: `(defun elt-eg() (elt '(1560 1561 1562) 2))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] (1560 1561 1562)
 1  193   constant[1] 2
 2  156   elt
 3  135   return

Constants Vector: [(1560 1561 1562) 2]
```

nreverse (159)

nreverse (159)

Call `nreverse` with one stack argument.

Implements:
`TOS <- (elt TOS)`.

Generated via:
`nreverse`.

Instruction size:
1 byte

Stack effect:
$-1+1$.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: `(defun nreverse-eg() (nreverse '(1590 1591)))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] (1590 1591)
 1  159   nreverse
 2  135   return

Constants Vector: [(1590 1591)]
```

setcar (160)

`setcar` (160)

Call `setcar` with two stack arguments.

Implements:
`S[1] <- (setcar S[1] TOS); top--`.

Generated via:
`setcar`.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: With lexical binding in effect, `(defun setcar-eg(l) (setcar l 1600))` generates:

```
PC  Byte  Instruction
 0  137   dup
 1  192   constant[0] 1600
 2  160   setcar
 3  135   return

Constants Vector: [1600]
```

setcdr (161)

`setcdr` (161)

Call `setcdr` with two stack arguments.

Implements:
`S[1] <- (setcdr S[1] TOS); top--`.

Generated via:
`setcdr`.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: With lexical binding in effect, `(defun setcdr-eg(l) (setcdr l 1610))` generates:

```
PC  Byte  Instruction
 0  137   dup
 1  192   constant[0] 1610
 2  161   setcdr
 3  135   return

Constants Vector: [1610]
```

car-safe (162)

`car-safe` (162)

Call `car-safe` with one argument.

Implements:
`TOS <- (car-safe TOS)`.

Generated via:
`car-safe`.

Instruction size:
1 byte

Stack effect:
$-1+1$.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: With lexical binding in effect, `(defun car-safe-eg(l) (car-safe l))` generates:

```
PC  Byte  Instruction
 0  137   dup
 1  162   car-safe
 2  135   return
```

cdr-safe (163)

`cdr-safe` (163)

Call `cdr-safe` with one stack argument.

Implements:
`TOS <- (cdr-safe TOS)`.

Generated via:
`cdr-safe`.

Instruction size:
1 byte

Stack effect:
$-1+1$.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: With lexical binding in effect, `(defun cdr-safe-eg(l) (cdr-safe l))` generates:

```
PC  Byte  Instruction
 0  137   dup
 1  163   cdr-safe
 2  135   return
```

nconc (164)

nconc (164)

Call `nconc` with two stack arguments.

Implements:
`S[1] <- (nconc S[1] TOS); top--`.

Generated via:
`nconc`.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: With lexical binding in effect, `(defun nconc-eg(a b) (nconc a b))` generates:

```
PC  Byte  Instruction
 0    1   stack-ref[1]
 1    1   stack-ref[1]
 2  164   nconc
 3  135   return
```

3.6.3 Arithmetic Function Instructions

These instructions correspond to general functions which are not specific to Emacs; common cases are usually inlined for speed by the bytecode interpreter.

`sub1` (83)

Call `1-`.

Implements:
`TOS <- (1- TOS)`.

Generated via:
`1-`.

Instruction size:
1 byte

Stack effect:
$-1 + 1$.

Example: When lexical binding is in effect, `(defun sub1-eg(n) (1- n))` generates:

```
PC  Byte  Instruction
 0  137   dup
 1   83   sub1
 2  135   return
```

add1 (84)

add1 (84)

Call 1+.

Implements:
TOS <- (1+ TOS).

Generated via:
unary -.

Instruction size:
1 byte

Stack effect:
$-1+1$.

Example: When lexical binding is in effect, (defun add1-eg(n) (1+ n)) generates:

```
PC  Byte  Instruction
 0  137   dup
 1   84   add1
 2  135   return
```

eqlsign (85)

`eqlsign` (85)

Call `=`.

Implements:
`S[1] <- (= S[1] TOS); top--`.

Generated via:
binary `=`.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Example: When dynamic binding is in effect, `(defun eqlsign-eg(a b) (= a b))` generates:

```
PC  Byte  Instruction
 0    8   varref[0] a
 1    9   varref[1] b
 2   85   eqlsign
 3  135   return

Constants Vector: [a b]
```

gtr (86)

gtr (86)

Call `>`.

Implements:

`S[1] <- (> S[1] TOS); top--`.

Generated via:

`>`.

Instruction size:

1 byte

Stack effect:

$-2+1$.

Example: When lexical binding is in effect, `(defun gtr-eg(a b) (> a b))` generates:

```
PC  Byte  Instruction
 0    1   stack-ref[1]
 1    1   stack-ref[1]
 2   86   gtr
 3  135   return
```

lss (87)

`lss` (87)

Call `<`.

Implements:

`S[1] <- (< S[1] TOS); top--`.

Generated via:

`<`.

Instruction size:

1 byte

Stack effect:

$-2+1$.

Example: When dynamic binding is in effect, `(defun lss-eg(a b) (< a b))` generates:

```
PC  Byte  Instruction
 0    8   varref[0] a
 1    9   varref[1] b
 2   87   lss
 3  135   return

Constants Vector: [a b]
```

leq (88)

`leq` (88)

Call `<=`.

Implements:
`S[1] <- (<= S[1] TOS); top--`.

Instruction size:
1 byte

Generated via:
`<=`.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Example: When dynamic binding is in effect, `(defun leq-eg(a b) (<= a b))` generates:

```
PC  Byte  Instruction
 0    8   varref[0] a
 1    9   varref[1] b
 2   88   leq
 3  135   return

Constants Vector: [a b]
```

geq (89)

geq (89)

Call `>=`.

Implements:
`S[1] <- (>= S[1] TOS); top--`.

Instruction size:
1 byte

Generated via:
`>=`.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Example: When lexical binding is in effect, `(defun geq-eg(a b) (>= a b))` generates:

```
PC  Byte  Instruction
 0    1   stack-ref[1]
 1    1   stack-ref[1]
 2   89   geq
 3  135   return
```

diff (90)

`diff` (90)

Call binary `-`.

Implements:
`S[1] <- (- S[1] TOS); top--`.

Generated via:
binary `-`.

Instruction size:
1 byte

Instruction size:
1 byte

Stack effect:
$-2+1$.

Example: When lexical binding is in effect, `(defun diff-eg(a b) (- a b))` generates:

```
PC  Byte  Instruction
 0    1   stack-ref[1]
 1    1   stack-ref[1]
 2   90   diff
 3  135   return
```

negate (91)

`negate` (91)

Call unary `-`.

Implements:
`TOS <- (- TOS)`.

Generated via:
unary `-`.

Instruction size:
1 byte

Instruction size:
1 byte

Stack effect:
$-1+1$.

Example: When lexical binding is in effect, `(defun negate-eg(a) (- a))` generates:

```
PC  Byte  Instruction
 0    8   varref[0] a
 1   91   negate
 2  135   return

Constants Vector: [a]
```

plus (92)

plus (92)

Call unary +.

Implements:
S[1] <- (+ S[1] TOS); top--.

Generated via:
+.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Example: When dynamic binding is in effect, (defun plus-eg(n) (+ n n)) generates:

```
PC  Byte  Instruction
 0    8   varref[0] n
 1  137   dup
 2   92   plus
 3  135   return

Constants Vector: [n]
```

mult (95)

`mult` (95)

Call `*`.

Implements:
`S[1] <- (* S[1] TOS); top--`.

Generated via:
`*`.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: When dynamic binding is in effect, `(defun mult-eg(n) (* n n))` generates:

```
PC  Byte  Instruction
 0    8   varref[0] n
 1  137   dup
 2   95   mult
 3  135   return

Constants Vector: [n]
```

max (93)

max (93)

Call max.

Implements:
S[1] <- (max S[1] TOS); top--.

Generated via:
max.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Example: When dynamic binding is in effect, (defun max-eg(a b) (max a b)) generates:

```
PC  Byte  Instruction
 0    8   varref[0] a
 1    9   varref[1] b
 2   93   max
 3  135   return

Constants Vector: [a b]
```

min (94)

`min` (94)

Call `min`.

Implements:
`TOS <- (min(S[1] TOS)`.

Generated via:
binary `min`.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Example: When dynamic binding is in effect, `(defun min-eg(a b) (min a b))` generates:

```
PC  Byte  Instruction
 0    8   varref[0] a
 1    9   varref[1] b
 2   94   min
 3  135   return

Constants Vector: [a b]
```

quo (165)

quo (165)

Call `/`.

Implements:
`S[1] <- (/ S[1] TOS); top--`.

Generated via:
`/`.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Example: When dynamic binding is in effect, `(defun min-quo(a b) (/ a b))` generates:

```
PC  Byte  Instruction
 0    8   varref[0] a
 1    9   varref[1] b
 2  165   quo
 3  135   return

Constants Vector: [a b]
```

rem (166)

`rem` (166)

Call `%`.

implements:
`S[1] <- (% S[1] TOS); top--`.

generated via:
`%`

Instruction size:
1 byte

Stack effect:
$-2+1$

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: When lexical binding is in effect, `(defun rem-eg(a b) (% a b))` generates:

```
PC  Byte  Instruction
 0    1   stack-ref[1]
 1    1   stack-ref[1]
 2  166   rem
 3  135   return
```

3.6.4 String Function Instructions

These instructions correspond to general functions which are not specific to Emacs; the bytecode interpreter calls the corresponding C function for them.

`substring` (79)

Call `substring` with three stack arguments.

Implements:
`S[2] <- (substring S[2] S[1] TOS); top-=2`.

Generated via:
`substring`.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Example: `(defun substring-eg() (substring "abc" 0 2))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] "abc"
 1  193   constant[1] 0
 2  194   constant[2] 2
 3   79   substring
 4  135   return

Constants Vector: ["abc" 0 2]
```

concat2 (80)

`concat2` (80)

Call `concat` with two stack arguments.

Implements:
`S[1] <- (concat S[1] TOS); top--`.

Generated via:
`concat`.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: `(defun concat2-eg() (concat "a" "b"))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] "a"
 1  193   constant[1] "b"
 2   80   concat2
 3  135   return

Constants Vector: ["a" "b"]
```

concat3 (81)

concat3 (81)

Call `concat` with three stack arguments.

Implements:

`S[2] <- (concat S[2] S[1] TOS); top-=2`.

Generated via:

`concat`.

Instruction size:

1 byte

Stack effect:

$-2+1$.

Example: `(defun concat3-eg() (concat "a" "b" "c"))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] "a"
 1  193   constant[1] "b"
 2  194   constant[2] "c"
 3   81   concat3
 4  135   return

Constants Vector: ["a" "b" "c"]
```

concat4 (82)

concat4 (82)

Call concat with four stack stack arguments.

Implements:

S[3] <- (concat S[3] S[2] S[1] TOS); top -= 2.

Generated via:

concat.

Instruction size:

1 byte

Stack effect:

$-4+1$.

Example: (defun concat4-eg() (concat "a" "b" "c" "d")) generates:

```
PC  Byte  Instruction
 0  192   constant[0] "a"
 1  193   constant[1] "b"
 2  194   constant[2] "c"
 3  195   constant[3] "d"
 4   82   concat4
 5  135   return

Constants Vector: ["a" "b" "c" "d"]
```

concatN (174)

`concatN` (174)

Call `concat` on up to 255 stack arguments. Note there are special instructions for the case where there are 2 to 4 items to concatenate.

Implements:
`S[n-1] <- (concat S[n-1] S[n-2] ... TOS); top -= (n-1)`.

Generated via:
`concat`.

Operand: 8-bit number of items in concat

Instruction size:
2 bytes

Stack effect:
$-n+1$ where n is the value of the instruction operand.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: `(defun concatN-eg() (concat "a" "b" "c" "d" "e"))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] "a"
 1  193   constant[1] "b"
 2  194   constant[2] "c"
 3  195   constant[3] "d"
 4  196   constant[4] "e"
 5  176   concatN [5]
           5
 7  135   return

Constants Vector: ["a" "b" "c" "d" "e"]
```

upcase (150)

upcase (150)

Call `upcase` with one stack argument.

Implements:
`TOS <- (upcase TOS)`.

Generated via:
`upcase`.

Instruction size:
1 byte

Stack effect:
$-1+1$.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: `(defun upcase-eg() (upcase "abc"))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] "abc"
 1  150   upcase
 2  135   return

Constants Vector: ["abc"]
```

downcase (151)

`downcase` (151)

Call `downcase` with one argument.

Implements:
`TOS <- (downcase TOS)`.

Generated via:
`downcase`.

Instruction size:
1 byte

Stack effect:
$-1+1$.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: `(defun downcase-eg(l) (downcase "ABC"))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] "ABC"
 1  151   downcase
 2  135   return

Constants Vector: ["ABC"]
```

stringeqlsign (152)

`stringeqlsign` (152)

Call `string=` with two stack arguments, comparing two strings for equality.

Implements:
`S[1] <- (string= S[1] TOS); top--`.

Generated via:
`string=`.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: With lexical binding in effect,

```
(defun stringeqlsign-eg(a)
  (string= a "b"))
```

generates:

```
PC  Byte  Instruction
 0  137   dup
 1  192   constant[0] "b"
 2  152   string=
 3  135   return

Constants Vector: ["b"]
```

stringlss (153)

`stringlss` (153)

Call `string<` with two stack arguments, comparing two strings.

Implements:
`S[1] <- (string< S[1] TOS); top--`.

Generated via:
`string<`.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: With lexical binding in effect,

```
(defun stringlss-eg(a)
  (string< a "b"))
```

generates:

```
PC  Byte  Instruction
 0  137   dup
 1  192   constant[0] "b"
 2  153   string<
 3  135   return

Constants Vector: ["b"]
```

3.6.5 Emacs Buffer Instructions

current-buffer (112)

Call `current-buffer`.

Implements:

```
TOS <- (current-buffer)
```

Generated via:

`current-buffer`

Instruction size:

1 byte

Stack effect:

$-0+1$.

Example: `(defun current-buffer-eg() (current-buffer))` generates:

```
PC  Byte  Instruction
 0  112   current-buffer
 1  135   return
```

set-buffer (113)

`set-buffer` (113)

Call `set-buffer` with TOS.

Implements:

`TOS <- (set-buffer TOS)`

Generated via:

`set-buffer`

Instruction size:

1 byte

Stack effect:

$-1+1$.

Example: `(defun set-buffer-eg() (set-buffer "*scratch"))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] "*scratch"
 1  113   set-buffer
 2  135   return

Constants Vector: ["*scratch"]
```

save-current-buffer-1 (114)

`save-current-buffer-1` (114)

Call `save-current-buffer`.

Replaces older `save-current-buffer`. See [save-current-buffer], page 139.

Implements:

`TOS <- (save-current-buffer)`

Generated via:

`save-current-buffer`

Instruction size:

1 byte

Stack effect:

$-1+1$.

Added in: Emacs 22. See Section 4.5 [Emacs 22], page 147.

Example:

```
(defun save-current-buffer-1-eg()
   (save-current-buffer (prog 5)))}
```

generates:

```
PC  Byte  Instruction
 0  114   save-current-buffer
 1  192   constant[0] prog
 2  193   constant[1] 5
 3   33   call[1]
 4   41   unbind[1]
 5  135   return

Constants Vector: [prog 5]
```

buffer-substring (123)

`buffer-substring` (123)

Call `buffer-substring` with two stack arguments.

Implements:
`S[1] <- (buffer-substring S[1] TOS); top--`.

Generated via:
`buffer-substring`.

Instruction size:
1 byte

Stack effect:
$-2+1$. Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: `(defun buffer-substring-eg() (buffer-substring 1230 1231))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] 1230
 1  193   constant[1] 1231
 2  123   buffer-substring
 3  135   return

Constants Vector: [1230 1231]
```

3.6.6 Emacs Position Instructions

These instructions correspond to Emacs-specific position functions that are found in the "Positions" chapter of the Emacs Lisp Reference Manual. They are not inlined by the bytecode interpreter, but simply call the corresponding C function.

`point` (96)

Call `point`.

Implements:
`TOS <- (point)`

Generated via:
`point`

Instruction size:
1 byte

Stack effect:
$-0+1$.

Added in: Emacs 18.31, renamed from `dot`. See Section 4.1 [Emacs 18], page 143.

Example: `(defun point-eg() (point))` generates:

```
PC  Byte  Instruction
 0   96   point
 1  135   return
```

goto-char (98)

goto-char (98)

Call `goto-char` with one stack argument.

Implements:

`TOS <- (goto-char TOS)`

Generated via:

`goto-char`

Instruction size:

1 byte

Stack effect:

$-1+1$.

Example: With lexical binding in effect, `(defun goto-char-eg(n) (goto-char n))` generates:

```
PC  Byte  Instruction
 0  137   dup
 1   98   goto-char
 2  135   return
```

point-max (100)

`point-max` (100)

Call `point-max`.

Implements:
`TOS <- (point-max)`

Generated via:
`point-max`

Instruction size:
1 byte

Stack effect:
$-0+1$.

Added in: Emacs 18.31, renamed from `dot-max`. See Section 4.1 [Emacs 18], page 143.

Example: `(defun point-max-eg() (point-max))` generates:

```
PC  Byte  Instruction
 0  100   point-max
 1  135   return
```

point-min (101)

`point-min` (101)

Call `point-min`.

Implements:
`TOS <- (point-min)`

Generated via:
`point-min`

Instruction size:
1 byte

Stack effect:
$-0+1$.

Added in: Emacs 18.31, renamed from `dot-min`. See Section 4.1 [Emacs 18], page 143.

Example: `(defun point-min-eg() (point-min))` generates:

```
PC  Byte  Instruction
 0  101   point-min
 1  135   return
```

forward-char (117)

`forward-char` (117)

Call `forward-char` with one stack argument.

Implements:

`TOS <- (forward-char TOS)`

Generated via:

`forward-char`

Instruction size:

1 byte

Stack effect:

$-1+1$.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: `(defun forward-char-eg() (forward-char 1))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] 1
 1  117   forward-char
 2  135   return

Constants Vector: [1]
```

forward-word (118)

`forward-word` (118)

Call `forward-word` with one stack argument.

Implements:

```
TOS <- (forward-word TOS)
```

Generated via:

`forward-word`

Instruction size:

1 byte

Stack effect:

$-1+1$.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: `(defun forward-word-eg() (forward-word 1))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] 1
 1  118   forward-word
 2  135   return

Constants Vector: [1]
```

forward-line (121)

`forward-line` (121)

Call `forward-line` with one stack argument.

Implements:

```
TOS <- (forward-line TOS)
```

Generated via:

`forward-line`

Instruction size:

1 byte

Stack effect:

$-1+1$.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: `(defun forward-line-eg() (forward-line 1))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] 1
 1  121   forward-line
 2  135   return

Constants Vector: [1]
```

skip-chars-forward (119)

skip-chars-forward (119)

Call `skip-chars-forward` with two stack arguments.

Implements:
`S[1] <- (skip-chars-forward S[1] TOS); top--`.

Generated via:
`skip-chars-forward`.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: `(defun skip-chars-forward-eg() (skip-chars-forward "aeiou" 3))`
generates:

```
PC  Byte  Instruction
 0  192   constant[0] "aeiou"
 1  193   constant[1] 3
 2  119   skip-chars-forward
 3  135   return

Constants Vector: ["aeiou" 3]
```

skip-chars-backward (120)

`skip-chars-backward` (120)

Call `skip-chars-backward` with two stack arguments.

Implements:
`S[1] <- (skip-chars-backward S[1] TOS); top--`.

Generated via:
`skip-chars-backward`.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: `(defun skip-chars-backward-eg() (skip-chars-backward "aeiou" 3))`
generates:

```
PC  Byte  Instruction
 0  192   constant[0] "aeiou"
 1  193   constant[1] 3
 2  120   skip-chars-backward
 3  135   return

Constants Vector: ["aeiou" 3]
```

narrow-to-region (125)

narrow-to-region (125)

Call `narrow-to-region` with two stack arguments.

Implements:
`S[1] <- (narrow-to-region S[1] TOS); top--`.

Generated via:
`narrow-to-region`.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: `(defun narrow-to-region-eg() (narrow-to-region 1250 1251))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] 1250
 1  193   constant[1] 1251
 2  125   narrow-to-region
 3  135   return

Constants Vector: [1250 1251]
```

widen (126)

`widen` (126)

Call `widen`.

Implements:
`TOS <- (widen)`

Generated via:
`widen`

Instruction size:
1 byte

Stack effect:
$-0+1$.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: `(defun widen-eg() (widen))` generates:

```
PC  Byte  Instruction
 0  126   widen
 1  135   return
```

3.6.7 Emacs Text Instructions

These instructions correspond to Emacs-specific text manipulation functions found in the "Text" chapter of the Emacs Lisp Reference Manual. They are not inlined by the bytecode interpreter, but simply call the corresponding C function.

`insert` (99)

Call `insert` with one stack argument.

Implements:

`TOS <- (insert TOS)`

Generated via:

`insert`

Instruction size:

1 byte

Stack effect:

$-1+1$.

Example: With lexical binding in effect, `(defun insert-eg(n) (insert n))` generates:

```
PC  Byte  Instruction
 0  137   dup
 1   99   insert
 2  135   return
```

insertN (99)

`insertN` (99)

Call `insert` on up to 255 stack arguments. Note there is a special instruction when there is only one stack argument.

Implements:
`S[n-1] <- (insert S[n-1] S[n-2] ... TOS); top -= (n-1)`.

Generated via:
`insert`

Operand: 8-bit number of items in concat

Instruction size:
2 bytes

Stack effect:
$-n+1$ where n is the value of the instruction operand.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: With lexical binding in effect, `(defun insertN-eg(a b c) (insert a b c))` generates:

```
PC  Byte  Instruction
 0    2   stack-ref[2]
 1    2   stack-ref[2]
 2    2   stack-ref[2]
 3  177   insertN [3]
           3
 5  135   return
```

char-after (102)

`char-after` (102)

Call `char-after` with one stack argument.

Implements:
`TOS <- (char-after TOS)`

Generated via:
`char-after`

Instruction size:
1 byte

Stack effect:
$-1+1$.

Example: `(defun char-after-eg() (char-after))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] nil
 1  102   char-after
 2  135   return

Constants Vector: [nil]
```

following-char (103)

following-char (103)

Call following-char.

Implements:
TOS <- (following-char TOS)

Generated via:
following-char

Instruction size:
1 byte

Stack effect:
$-1+1$.

Example: (defun following-char-eg() (following-char)) generates:

```
PC  Byte  Instruction
 0  103   following-char
 1  135   return
```

preceding-char (104)

preceding-char (104)

Call `preceding-char`.

Implements:

`TOS <- (preceding-char TOS)`

Generated via:

`preceding-char`

Instruction size:

1 byte

Stack effect:

$-1+1$.

Example: `(defun preceding-char-eg() (preceding-char))` generates:

```
PC  Byte  Instruction
 0  104   preceding-char
 1  135   return
```

current-column (105)

current-column (105)

Call current-column.

Implements:

TOS <- (current-column)

Generated via:

current-column

Instruction size:

1 byte

Stack effect:

$-0+1$.

Example: (defun current-column-eg() (current-column)) generates:

```
PC  Byte  Instruction
 0  105   current-column
 1  135   return
```

eolp (108)

`eolp` (108)

Call `eolp`.

Implements:
`TOS <- (eolp)`

Generated via:
`eolp`

Instruction size:
1 byte

Stack effect:
$-0+1$.

Example: `(defun eolp-eg() (eolp))` generates:

```
PC  Byte  Instruction
 0  108   eolp
 1  135   return
```

eobp (109)

`eobp` (109)

Call `eobp`.

Implements:
`TOS <- (eobp)`

Generated via:
`eobp`

Instruction size:
1 byte

Stack effect:
$-0+1$.

Example: `(defun eobp-eg() (eobp))` generates:

```
PC  Byte  Instruction
 0  109   eobp
 1  135   return
```

bolp (110)

`bolp` (110)

Call `bolp`.

Implements:
`TOS <- (bolp)`

Generated via:
`bolp`

Instruction size:
1 byte

Stack effect:
$-0+1$.

Example: `(defun bolp-eg() (bolp))` generates:

```
PC  Byte  Instruction
 0  110   bolp
 1  135   return
```

bobp (111)

bobp (111)

Call bobp.

Implements:

TOS <- (bobp)

Generated via:

bobp

Instruction size:

1 byte

Stack effect:

$-0+1$.

Example: (defun bobp-eg() (bobp)) generates:

```
PC  Byte  Instruction
 0  111   bobp
 1  135   return
```

delete-region (124)

`delete-region` (124)

Call `delete-region` with two stack arguments.

Call `delete-region` with two stack arguments.

Implements:
`S[1] <- (delete-region S[1] TOS); top--`.

Generated via:
`delete-region`.

Instruction size:
1 byte

Stack effect:
$-2+1$.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: `(defun delete-region-eg() (delete-region 1240 1241))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] 1240
 1  193   constant[1] 1241
 2  124   delete-region
 3  135   return

Constants Vector: [1240 1241]
```

end-of-line (127)

`end-of-line` (127)

Call `end-of-line` with one stack argument.

Implements:
`(end-of-line TOS; top--`

Generated via:
`delete-region`.

Instruction size:
1 byte

Stack effect:
$-1+0-$.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: `(defun end-of-line-eg() (end-of-line))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] nil
 1  127   end-of-line
 2  135   return

Constants Vector: [nil]
```

3.6.8 Emacs Misc Function Instructions

These instructions correspond to miscellaneous Emacs-specific functions. They are not inlined by the bytecode interpreter, but simply call the corresponding C function.

`char-syntax` (122)

Call `char-syntax` with one stack argument.

Implements:

```
TOS <- (char-syntax TOS)
```

Generated via:

`char-syntax`

Instruction size:

1 byte

Stack effect:

$-1 + 1$.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: `(defun char-syntax-eg() (char-syntax ?a))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] 97
 1  122   char-syntax
 2  135   return

Constants Vector: [97]
```

save-excursion (138)

`save-excursion` (138)

Make a binding recording buffer, point, and mark.

This instruction manipulates the special-bindings stack by creating a new binding when executed. It needs to be balanced with `unbind` instructions.

Implements:
`(save-excursion)`.

Generated via:
`save-excursion`

Instruction size:
1 byte

Stack effect:
$-0+0$.

Example: When lexical binding is in effect, `(defun save-excursion-eg() (save-excursion 1380))` generates:

```
PC  Byte  Instruction
 0  138   save-excursion
 1  192   constant[0] 1380
 2   41   unbind[1]
 3  135   return

Constants Vector: [1380]
```

set-marker (147)

`set-marker` (147)

Call `set-marker` with three stack arguments.

Implements:
`S[2] <- (set-marker S[2] S[1] TOS); top -= 2`.

Generated via:
`set-marker`

Instruction size:
1 byte

Stack effect:
$-3+1$.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: When lexical binding is in effect, `(defun set-marker-eg(marker position) (set-marker marker position))` generates:

```
PC  Byte  Instruction
 0    1   stack-ref[1]
 1    1   stack-ref[1]
 2  192   constant[0] nil
 3  147   set-marker
 4  135   return

Constants Vector: [nil]
```

match-beginning (148)

`match-beginning` (148)

Call `match-beginning` with one stack argument.

Implements:
`TOS <- (match-beginning TOS)`

Generated via:
`match-beginning`

Instruction size:
1 byte

Stack effect:
$-1+1$.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: `(defun match-beginning-eg() (match-beginning 1))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] 1
 1  148   match-beginning
 2  135   return

Constants Vector: [1]
```

match-end (149)

`match-end` (149)

Call `match-end` with one stack argument.

Implements:
`TOS <- (match-end TOS)`

Generated via:
`match-end`

Instruction size:
1 byte

Stack effect:
$-1+1$.

Added in: Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

Example: `(defun match-end-eg() (match-end 1))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] 1
 1  148   match-end
 2  135   return

Constants Vector: [1]
```

3.7 Stack-Manipulation Instructions

`discard` (136)

Discard one value from the stack.

Implements:
`top--`

Instruction size:
1 byte

Generated via:
Function calls that do not use the returned value; the end of `let` forms in lexical binding to remove locally-bound variables.

Stack effect:
$-1 + 0$.

Example: `(defun discard-eg() (exchange-point-and-mark) (point))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] exchange-point-and-mark
 1   32   call[0]
 2  136   discard
 3   96   point
 4  135   return

Constants Vector: [exchange-point-and-mark]
```

discardN (180)

`discardN` (180)

Discards up to 127 arguments from the stack. Note there is a special instruction when there is only one argument.

Implements:
`if (n & 8) S[n] <- TOS; top -= n & 7;` where `n` where `n` is the value of the operand.

operand: 7-bit number of items to discard. The top 8th bit when set indicates to keep the old TOS value after discarding.

Instruction size:
2 bytes

Generated via:
Function calls that do not use the returned value; the end of `let` forms in lexical binding with optimization to remove locally-bound variables.

Stack effect:
$-n+0$

Added in: Emacs 24.1. See Section 4.7 [Emacs 24], page 148.

Example: When lexical binding is in effect and optimization are in effect,

```
(1+ (let ((a 1) (_b) (_c)) a)))
```

generates:

```
PC  Byte  Instruction
 0  192   constant[0] 1
 1  193   constant[1] nil
 2  137   dup
 3    2   stack-ref[2]
 4  182   discardN [131]
         131
 6   84   add1
 7  135   return

Constants Vector: [1 nil]
```

dup (137)

dup (137)

Make a copy of the top-of-stack value and push that onto the top of the evaluation stack.

Implements:

`top++; TOS <- S[1]`

Generated via:

`setq` in dynamic bindings to set a value and then use it. In lexical binding, to use the first argument parameter.

Instruction size:

1 byte

Stack effect:

$-0+1$.

Example: When lexical binding is in effect,

generates:

```
PC  Byte  Instruction
 0  137   dup  ;; duplicates top of stack, argument n
 1  135   return
```

stack-set (178)

`stack-set` (178)

Sets a value on the evaluation stack to TOS.

Implements:

`S[i] <- TOS; top--` where `i` is the value of the instruction operand.

Note that `stack-set[0]` has the same effect as `discard`, but does a little more work to do this. `stack-set[1]` has the same effect as `discardN 1` with the top bit of `discardN` set to preserve `TOS`.

Generated via:

`let`, `let*` and lambda arguments.

Operand: A 8-bit integer stack index

Instruction size:

2 bytes

Stack effect:

$-1 + 0$.

Added in: Emacs 24.1. See Section 4.7 [Emacs 24], page 148.

Example: When lexical binding is in effect and optimization

```
defun stack-set-eg()
(let ((a 5) a)))
```

generates:

```
PC  Byte  Instruction
 0  192   constant[0] 5
 1  193   constant[1] nil
 2  193   constant[1] nil
 3  178   stack-set [2]
           2
 5  136   discard
 6  135   return

Constants Vector: [5 nil]
```

stack-set2 (179)

`stack-set2` (179)

Implements:

`S[i] <- TOS; top--` where `i` is the value of the instruction operand.

Note that `stack-set2[0]` has the same effect as `discard`, but does a little more work to do this. `stack-set2[1]` has the same effect as `discardN 1` with the top bit of `discardN` set to preserve `TOS`.

Generated via:

`let`, `let*` and lambda arguments.

Operand: A 16-bit integer stack index

Instruction size:

3 bytes

Stack effect:

$-1 + 0$.

Added in: Emacs 24.1. See Section 4.7 [Emacs 24], page 148.

Example: ??

3.8 Obsolete or Unused Instructions

These instructions are not generated. In some cases, they were generated in a older version of Emacs. In some cases the instructions were planned on being used but never were. In some cases, the instructions are still handled if they appear (such as from older bytecode), but in other cases they are no longer accepted by the interperter

`save-current-buffer` (97)

Replaced by `save-current-buffer-1`. See [save-current-buffer-1], page 104.

`mark` (97)

Used in V 17; obsolete in Emacs 18.31. See Section 4.1 [Emacs 18], page 143.

`scan-buffer` (107)

Obsolete in Emacs 18.31. See Section 4.1 [Emacs 18], page 143.

`read-char` (114)

`set-mark` (115)

Obsolete in Emacs 18.31. See Section 4.1 [Emacs 18], page 143.

`interactive-p` (116)

`save-window-excursion` (139)

Call `save-window-excursion`.

Implements:

`(save-window-excursion BLOCK)`

Generated via:

`save-window-excursion`

Instruction size:

1 byte

Stack effect:

$-1 + 0$.

Obsolete since:

Emacs 24.1. See Section 4.7 [Emacs 24], page 148. Now generates a sequence of bytecode that includes calls to `current-window-configuration` and `set-window-configuration`

Example:

```
(defun save-window-excursion()
   (save-window-excursion 1390))
```

generates:

```
PC  Byte  Instruction
 0  192   constant[0] (1390)
```

```
 1  139   save-window-excursion
 2  135   return

Constants Vector: [(1390)]
```

condition-case (143)

Replaced by `pushconditioncase`. See [pushconditioncase], page 32,

Implements:
?

Generated via:
?

Instruction size:
1 byte

Stack effect:
$-2+1$.

Obsolete since:
Emacs 24.4. See Section 4.7 [Emacs 24], page 148.

Example: `(defun condition-case-eg() (?))` generates:

temp-output-buffer-setup (144)

Implements:
Setup for `with-output-to-temp-buffer`.

Generated via:
`with-output-to-temp-buffer`

Instruction size:
1 byte

Stack effect:
$-1+0$.

Obsolete since:
Emacs 24.1. See Section 4.7 [Emacs 24], page 148.

Example: `(defun wottb-eg () (with-output-to-temp-buffer "wottb" 5))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] "wottb"
 1  144   temp-output-buffer-setup
 2  193   constant[1] 5
 3  145   temp-output-buffer-show
 4  135   return

Constants Vector: ["wottb" 5]
```

`temp-output-buffer-show` (145)

Implements:
Finishing code of `with-output-to-temp-buffer`.

Generated via:
`with-output-to-temp-buffer`

Instruction size:
1 byte

Stack effect:
$-0+0$.

Obsolete in:
Emacs 24.1. See Section 4.7 [Emacs 24], page 148.

Example: `(defun wottb-eg () (with-output-to-temp-buffer "wottb" 5))` generates:

```
PC  Byte  Instruction
 0  192   constant[0] "wottb"
 1  144   temp-output-buffer-setup
 2  193   constant[1] 5
 3  145   temp-output-buffer-show
 4  135   return

Constants Vector: ["wottb" 5]
```

`unbind-all` (146)

Introduced in Emacs 19.34 for tail-recursion elimination by jwz, but never used. See Section 4.2 [Emacs 19], page 144.

3.8.12 Relative Goto Instructions

In Emacs 19.34, Hallvard Furuseth introduced relative goto instrucitons. However, have never been generated in bytecode.

`Rgoto` (170)

Relative jump version of see [goto], page 34.

Introduced but unused in Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

`Rgotoifnil` (171)

Relative jump version of see [goto-if-nil], page 35.

Introduced but unused in Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

`Rgotoifnonnil` (172)

Relative-jump version of see [goto-if-not-nil], page 36.

Introduced but unused in Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

`Rgotoifnilelsepop` (173)

Relative-jump version of see [goto-if-nil-else-pop], page 37.

Introduced but unused in Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

`Rgotoifnonnilelsepop` (174)

Relative-jump version of see [goto-if-not-nil-else-pop], page 38.

Introduced but unused in Emacs 19.34. See Section 4.2 [Emacs 19], page 144.

4 Instruction Changes Between Emacs Releases

4.1 After 16 and Starting in 18.31

The following instructions were renamed:

- `dot` becomes `mark` (97). See [mark], page 139.
- `dot-min` becomes `point-min` (100). See [point-min], page 109.
- `dot-max` becomes `point-max` (101). See [point-max], page 108.

The following instructions became obsolete:

- `mark` (97). See [mark], page 139.
- `scan-buffer` (107). See [scan-buffer], page 139.
- `set-mark` (115). See [set-mark], page 139.

Version 18 Release History

- Emacs 18.31 was released Nov 23, 1986
- Emacs 18.32 was released Dec 6, 1986
- Emacs 18.33 was released Dec 12, 1986
- Emacs 18.35 was released Jan 5, 1987
- Emacs 18.36 was released Jan 21, 1987
- Emacs 18.37 was released Feb 11, 1987
- Emacs 18.38 was released Mar 3, 1987
- Emacs 18.39 was released May 14, 1987
- Emacs 18.40 was released Mar 18, 1987
- Emacs 18.41 was released Mar 22, 1987
- Emacs 18.44 was released Apr 15, 1987
- Emacs 18.46 was released Jun 8, 1987
- Emacs 18.47 was released Jun 15, 1987
- Emacs 18.48 was released Aug 30, 1987
- Emacs 18.49 was released Sep 17, 1987
- Emacs 18.50 was released Feb 13, 1988
- Emacs 18.51 was released May 6, 1988
- Emacs 18.52 was released Aug 31, 1988
- Emacs 18.59 was released Oct 30, 1988

4.2 After 18.59 and Starting 19.34

jwz and Hallvard made major changes and additions to the bytecode interpreter.

The following instructions were added:

- `mult` (97). See [mult], page 88.
- `forward-char` (117). See [forward-char], page 110.
- `forward-word` (118). See [forward-word], page 111.
- `skip-chars-forward` (119). See [skip-chars-forward], page 113.
- `skip-chars-backward` (120). See [skip-chars-backward], page 114.
- `forward-line` (121). See [forward-line], page 112.
- `char-syntax` (122). See [char-syntax], page 129.
- `buffer-substring` (123). See [buffer-substring], page 105.
- `delete-region` (124). See [delete-region], page 127.
- `narrow-to-region` (125). See [narrow-to-region], page 115.
- `widen` (126). See [widen], page 116.
- `end-of-line` (127). See [end-of-line], page 128.
- `unbind-all` (146). See [unbind-all], page 141.
- `set-marker` (147). See [set-marker], page 131.
- `match-beginning` (148). See [match-beginning], page 132.
- `match-end` (149). See [match-end], page 133.
- `upcase` (150). See [upcase], page 98.
- `downcase` (151). See [downcase], page 99.
- `stringeqlsign` (152). See [stringeqlsign], page 100.
- `stringlss` (153). See [stringlss], page 101.
- `equal` (154). See [equal], page 53.
- `nthcdr` (155). See [nthcdr], page 70.
- `elt` (156). See [elt], page 71.
- `member` (157). See [member], page 54.
- `assq` (158). See [assq], page 55.
- `nreverse` (159). See [nreverse], page 72.
- `setcar` (160). See [setcar], page 73.
- `setcdr` (161). See [setcdr], page 74.
- `car-safe` (162). See [car-safe], page 75.
- `cdr-safe` (163. See [cdr-safe], page 76.
- `nconc` (164). See [nconc], page 77.
- `quo` (165). See [quo], page 91.
- `rem` (166). See [rem], page 92.
- `numberp` (167). See [numberp], page 56.
- `integerp` (162). See [integerp], page 57.

- `Rgoto` (170). See [Rgoto], page 142.
- `Rgotoifnil` (171). See [Rgotoifnil], page 142.
- `Rgotoifnonnil` (172). See [Rgotoifnonnil], page 142.
- `Rgotoifnilelsepop` (173). See [Rgotoifnilelsepop], page 142.
- `Rgotoifnonnilelsepop` (174). See [Rgotoifnonnilelsepop], page 142.
- `listN` (175). See [listN], page 66.
- `concatN` (176). See [concatN], page 97.
- `insertN` (177). See [insertN], page 118.

Instruction `unbind-all` was added to support tail-recursion removal. However this was never subsequently implemented; so this intruction was never generated.

Starting in this version, unless C prepocessor variable `BYTE_CODE_SAFE` (off by default) is defined, the obsolete instructions listed in 18.59 are not implemented.

The following obsolete instructions throw an error when `BYTE_CODE_SAFE` is defined:

- `mark` (97)
- `scan-buffer` (107)
- `set-mark` (115)

Bytecode meta-comments look like this:

```
;;; compiled by rms@psilocin.gnu.ai.mit.edu on Mon Jun 10 17:37:37 1996
;;; from file /home/fsf/rms/e19/lisp/bytecomp.el
;;; emacs version 19.31.2.
;;; bytecomp version FSF 2.10
;;; optimization is on.
;;; this file uses opcodes which do not exist in Emacs 18.
```

Version 19 Release History

- Emacs 19.7 was released May 22 1993
- Emacs 19.8 was released May 25 1993
- Emacs 19.9 was released May 27 1993
- Emacs 19.10 was released May 30 1993
- Emacs 19.11 was released Jun 1, 1993
- Emacs 19.12 was released Jun 1, 1993
- Emacs 19.13 was released Jun 8, 1993
- Emacs 19.14 was released Jun 17, 1993
- Emacs 19.15 was released Jun 19, 1993
- Emacs 19.16 was released Jul 6, 1993
- Emacs 19.17 was released Jul 7, 1993
- Emacs 19.18 was released Aug 8, 1993
- Emacs 19.19 was released Aug 14, 1993
- Emacs 19.20 was released Nov 11, 1993
- Emacs 19.21 was released Nov 16, 1993

- Emacs 19.22 was released Nov 27, 1993
- Emacs 19.23 was released May 17, 1994
- Emacs 19.24 was released May 23, 1994
- Emacs 19.25 was released May 30, 1994
- Emacs 19.26 was released Sep 7, 1994
- Emacs 19.27 was released Sep 11, 1994
- Emacs 19.29 was released Jun 19, 1995
- Emacs 19.30 was released Nov 24, 1995
- Emacs 19.31 was released May 25, 1996
- Emacs 19.31 was released May 25, 1996
- Emacs 19.32 was released Aug 7, 1996
- Emacs 19.33 was released Sept 11, 1996

The Emacs Lisp tarball for 19.2 is Aug, 1992. (The tarball date for 19.2 is much later; and even after the date on the 20.1 tarball.)

4.3 After 19.34 and Starting in 20.1

`save-current-buffer` (97). See [save-current-buffer], page 139, and `save-current-buffer-1` (114) do the same thing, but the former is deprecated. The latter opcode replaces `read-char` which was not generated since v19.

I am not sure why the change; changing this opcode number however put it next to other buffer-related opcodes.

Bytecode meta-comments look like this:

```
;;; Compiled by rms@psilocin.gnu.ai.mit.edu on Sun Aug 31 13:07:37 1997
;;; from file /home/fsf/rms/e19/lisp/emacs-lisp/bytecomp.el
;;; in Emacs version 20.0.97.1
;;; with bytecomp version 2.33
;;; with all optimizations.
;;; This file uses opcodes which do not exist in Emacs 18.
```

Version 20 Release History

- Emacs 20.1 was released Sep 15, 1997
- Emacs 20.2 was released Sep 19, 1997
- Emacs 20.3 was released Aug 19, 1998
- Emacs 20.4 was released Jul 14, 1999

4.4 After 20.1 and Starting in 21.1

There were no instruction changes. However there were major changes in the bytecode interpreter.

An instruction with opcode 0 causes an abort.

Bytecode meta-comments look like this:

```
;;; Compiled by pot@pot.cnuce.cnr.it on Tue Mar 18 15:36:26 2003
;;; from file /home/pot/gnu/emacs-pretest.new/lisp/emacs-lisp/bytecomp.el
;;; in Emacs version 21.3
;;; with bytecomp version 2.85.4.1
;;; with all optimizations.
```

Version 21 Release History

- Emacs 21.1 was released Oct 20, 2001
- Emacs 21.2 was released Mar 16, 2002
- Emacs 21.3 was released Mar 18, 2003
- Emacs 21.4 was released Feb 6, 2005

4.5 After 21.4 and Starting in 22.1

There were no instruction changes.

The bytecode meta-comment no longer includess the bytecomp version used.

Bytecode meta-comments look like this:

```
;;; Compiled by cyd@localhost on Sat Jun  2 00:54:30 2007
;;; from file /home/cyd/emacs/lisp/emacs-lisp/bytecomp.el
;;; in Emacs version 22.1
;;; with all optimizations.

;;; This file uses dynamic docstrings, first added in Emacs 19.29.
```

Version 22 Release History

- Emacs 22.1 was released Jun 02, 2007
- The Emacs 22.2 tarball is dated Mar 26 2008
- The Emacs 22.3 tarball is dated Sep 05 2008

4.6 After 22.3 and Starting in 23.1

There were no instruction changes.

Bytecode meta-comments look like this:

```
;;; Compiled by cyd@furry on Wed Jul 29 11:15:02 2009
;;; from file /home/cyd/emacs/lisp/emacs-lisp/bytecomp.el
;;; in Emacs version 23.1
;;; with all optimizations.

;;; This file uses dynamic docstrings, first added in Emacs 19.29.
```

Version 23 Release History

- Emacs 23.1 was released Jul 29, 2009
- Emacs 23.2 was released May 7, 2010
- Emacs 23.3 was released Mar 7, 2011
- The Emacs 23.4 tarball is dated Jan 28, 2012

4.7 After 23.4 and Starting in 24.1

An error is thrown for unknown bytecodes rather than aborting.

The following instructions were added:

- `stack-set` (178). See [stack-set], page 137.
- `stack-set2`, (179). See [stack-set2], page 138.
- `discardN`, (180). See [discardN], page 135.

Unless C preprocessor variable `BYTE_CODE_SAFE` (off by default) is defined, obsolete instructions below and from earlier versions are not implemented.

- `temp-output-buffer-setup` (144). See [temp-output-buffer-setup], page 140.
- `temp-output-buffer-show` (145). See [temp-output-buffer-show], page 141.
- `save-window-excursion` (139). See [save-window-excursion], page 139.

Instruction `unbind-all`, which never was generated, was marked obsolete in this version.

The bytecode meta-comment no longer who user/hostname compiled and at what time. A message indicating whether utf-8 non-ASCII characters is used is included.

The following instructions were added in 24.4:

- `pophandler` (48). See [pophandler], page 31.
- `pushconditioncase` (49). See [pushconditioncase], page 32.
- `pushcatch` (50). See [pushcatch], page 33.

Bytecode meta-comments look like this:

```
;;; from file /misc/emacs/bzr/emacs24-merge/lisp/emacs-lisp/bytecomp.el
;;; in Emacs version 24.3
;;; with all optimizations.

;;; This file uses dynamic docstrings, first added in Emacs 19.29.

;;; This file does not contain utf-8 non-ASCII characters,
;;; and so can be loaded in Emacs versions earlier than 23.
```

Version 24 Release History

- The Emacs 24.1 tarball is dated Jun 10, 2012
- The Emacs 24.2 tarball is dated Aug 27, 2012
- Emacs 24.3 was released Mar 11, 2013
- Emacs 24.4 was released Oct 20, 2014
- Emacs 24.5 was released Apr 10, 2015

4.8 After 24.5 and Starting in 25.1

Instruction 0 becomes an error rather than aborting emacs.

A number of changes were made to `bytecode.c`.

The bytecode meta-comment no longer includes the source-code path.

Bytecode meta-comments look like this:

```
;;; Compiled
;;; in Emacs version 25.2
;;; with all optimizations.

;;; This file uses dynamic docstrings, first added in Emacs 19.29.

;;; This file does not contain utf-8 non-ASCII characters,
;;; and so can be loaded in Emacs versions earlier than 23.
```

Version 25 Release History

- Emacs 25.1 was released Sep 16, 2016
- The Emacs 25.2 tarball is dated Apr 21, 2017
- Emacs 25.3 was released Sep 11, 2017

4.9 After 25.3 and Starting in 26.1

The following instruction was added:

- `switch` (183) See commit 88549ec38e9bb30e338a9985d0de4e6263b40fb7.

4.10 After 26.1 and Starting in 27.1

No changes yet.

5 Opcode Table

In the table below, a `*` before the intruction name indicates an obsolete instruction, or instruction that is no longer generated by the bytecode compiler. On the other hand, `!` indicates not just an obsolete instruction, but one that no longer is interpreted. See Section 3.1 [Instruction-Description Format], page 20, for abbreviations used here, a description of how to interpret an opcode when it contains an index, and for a description of how to interpret the stack-effect field.

5.1 Opcodes (0000-0077)

Oct	Dec	Instruction	Size	Description	Stack
00	0			An error. Before 25.1 it is an immediate program abort! Logically `stack-ref[0]` but `dup` should be used instead.	
01	1	`stack-ref[1]`	1	See [stack-ref], page 23.	+1
02	2	`stack-ref[2]`	1	See [stack-ref], page 23.	+1
03	3	`stack-ref[3]`	1	See [stack-ref], page 23.	+1
04	4	`stack-ref[4]`	1	See [stack-ref], page 23.	+1
05	5	`stack-ref[5]`	1	See [stack-ref], page 23.	+1
06	6	`stack-ref[6]`	2	See [stack-ref], page 23.	+1
07	7	`stack-ref[7]`	3	See [stack-ref], page 23.	+1
010	8	`varref[0]`	1	See [varref], page 24.	+1
011	9	`varref[1]`	1	See [varref], page 24.	+1
012	10	`varref[2]`	1	See [varref], page 24.	+1
013	11	`varref[3]`	1	See [varref], page 24.	+1
014	12	`varref[4]`	1	See [varref], page 24.	+1
015	13	`varref[5]`	1	See [varref], page 24.	+1
016	14	`varref[6]`	2	See [varref], page 24.	+1
017	15	`varref[7]`	3	See [varref], page 24.	+1
020	16	`varset[0]`	1	See [varset], page 25.	−1
021	17	`varset[1]`	1	See [varset], page 25.	−1
022	18	`varset[2]`	1	See [varset], page 25.	−1
023	19	`varset[3]`	1	See [varset], page 25.	−1
024	20	`varset[4]`	1	See [varset], page 25.	−1
025	21	`varset[5]`	1	See [varset], page 25.	−1
026	22	`varset[6]`	2	See [varset], page 25.	−1
027	23	`varset[7]`	3	See [varset], page 25.	−1
030	24	`varbind[0]`	1	See [varbind], page 26.	−1
031	25	`varbind[1]`	1	See [varbind], page 26.	−1

032	26	`varbind[2]`	1	See [varbind], page 26.	-1
033	27	`varbind[3]`	1	See [varbind], page 26.	-1
034	28	`varbind[4]`	1	See [varbind], page 26.	-1
035	29	`varbind[5]`	1	See [varbind], page 26.	-1
036	30	`varbind[6]`	2	See [varbind], page 26.	-1
037	31	`varbind[7]`	3	See [varbind], page 26.	-1
040	32	`call0`	1	See [call], page 27.	$-1+1$
041	33	`call1`	1	See [call], page 27.	$-2+1$
042	34	`call2`	1	See [call], page 27.	$-3+1$
043	35	`call3`	1	See [call], page 27.	$-4+1$
044	36	`call4`	1	See [call], page 27.	$-5+1$
045	37	`call5`	1	See [call], page 27.	$-6+1$
046	38	`call6`	2	See [call], page 27.	$-n-1+1$
047	39	`call7`	3	See [call], page 27.	$-n-1+1$
050	40	`unbind0`	1	See [unbind], page 28.	-0
051	41	`unbind1`	1	See [unbind], page 28.	-0
052	42	`unbind2`	1	See [unbind], page 28.	-0
053	43	`unbind3`	1	See [unbind], page 28.	-0
054	44	`unbind4`	1	See [unbind], page 28.	-0
055	45	`unbind5`	1	See [unbind], page 28.	-0
056	46	`unbind6`	2	See [unbind], page 28.	-0
057	47	`unbind7`	3	See [unbind], page 28.	-0
060	48	`pophandler`	1		-0
061	49	`conditioncase`	3		$-1+\phi(0,+1)$
062	50	`pushconditioncase`	1		-0
063	51			Unused	
064	52			Unused	
065	53			Unused	
066	54			Unused	
067	55			Unused	
070	56	`nth`	1	See [nth], page 58.	$-2+1$
071	57	`symbolp`	1	See [symbolp], page 41.	$-1+1$
072	58	`consp`	1	See [consp], page 42.	$-1+1$
073	59	`stringp`	1	See [stringp], page 43.	$-1+1$
074	60	`listp`	1	See [listp], page 44.	$-1+1$
075	61	`eq`	1	See [eq], page 45.	$-2+1$
076	62	`memq`	1	See [memq], page 46.	$-2+1$
077	63	`not`	1	See [not], page 47.	$-1+1$

5.2 Opcodes (0100-0177)

Oct	Dec	Instruction	Size	Description	Stack
0100	64	car	1	See [car], page 59.	−1 + 1
0101	65	cdr	1	See [cdr], page 60.	−1 + 1
0102	66	cons	1	See [cons], page 61.	−2 + 1
0103	67	list1	1	See [list1], page 62.	−1 + 1
0104	68	list2	1	See [list2], page 63.	−2 + 1
0105	69	list3	1	See [list3], page 64.	−3 + 1
0106	70	list4	1	See [list4], page 65.	−4 + 1
0107	71	length	1	See [length], page 67.	−1 + 1
0110	72	aref	1	See [aref], page 68.	−2 + 1
0111	73	aset	1	See [aset], page 69.	−3 + 1
0112	74	symbol-value	1	See [symbol-value], page 48.	−1 + 1
0113	75	symbol-function	1	See [symbol-function], page 49.	−1 + 1
0114	76	set	1	See [set], page 50.	−2 + 1
0115	77	fset	1	See [fset], page 51.	−2 + 1
0116	78	get	1	See [get], page 52.	−2 + 1
0117	79	substring	1	See [substring], page 93.	−3 + 1
0120	80	concat2	1	See [concat2], page 94.	−2 + 1
0121	81	concat3	1	See [concat3], page 95.	−3 + 1
0122	82	concat4	1	See [concat4], page 96.	−4 + 1
0123	83	sub1	1	See [sub1], page 78.	−1 + 1
0124	84	add1	1	See [add1], page 79.	−1 + 1
0125	85	eqlsign	1	See [eqlsign], page 80.	−2 + 1
0126	86	gtr	1	See [gtr], page 81.	−2 + 1
0127	87	lss	1	See [lss], page 82.	−2 + 1
0130	88	leq	1	See [leq], page 83.	−2 + 1
0131	89	geq	1	See [geq], page 84.	−2 + 1
0132	90	diff	1	See [diff], page 85.	−2 + 1
0133	91	negate	1	See [negate], page 86.	−1 + 1
0134	92	plus	1	See [plus], page 87.	−2 + 1
0135	93	max	1	See [max], page 89.	−2 + 1
0136	94	min	1	See [min], page 90.	
0135	95	mult	1	See [mult], page 88.	−2 + 1
0140	96	point	1	See [point], page 106.	
0141	*97	*mark	1	See [mark], page 139,	−0 + 1
0142	98	goto-char	1	See [goto-char], page 107.	−1 + 1
0143	99	insert	1	See [insert], page 117.	−1 + 1
0145	100	point-max	1	See [point-max], page 108.	−0 + 1
0146	101	point-min	1	See [point-min], page 109.	−0 + 1
0144	102	char-after	1	See [char-after], page 119.	−1 + 1
0147	103	following-char	1	See [following-char], page 120.	−0 + 1

0150	104	preceding-char	1	See [preceding-char], page 121.	$-0+1$
0151	105	current-column	1	See [current-column], page 122.	$-0+1$
0153	*107	*scan-buffer		See [scan-buffer], page 139.	
0154	108	eolp	1	See [eolp], page 123.	$-0+1$
0155	109	eobp	1	See [eobp], page 124.	$-0+1$
0156	110	bolp	1	See [bolp], page 125.	$-0+1$
0157	111	bobp	1	See [bobp], page 126.	$-0+1$
0160	112	current-buffer	1	See [current-buffer], page 102.	$-0+1$
0161	113	set-buffer	1	See [set-buffer], page 103.	$-1+1$
0162	114	save-current-buffer-1	1	See [save-current-buffer-1], page 104.	-0
0162	*114	*read-char	1	See [read-char], page 139.	$+1$
0163	*115	*set-mark	1	See [set-mark], page 139.	-0
0164	*116	*interactive-p	1	See [interactive-p], page 139.	$+1$
0165	117	forward-char	1	See [forward-char], page 110.	$-1+1$
0166	118	forward-word	1	See [forward-word], page 111.	$-1+1$
0167	119	skip-chars-forward	1	See [skip-chars-forward], page 113.	$-2+1$
0170	120	skip-chars-backward	1	See [skip-chars-backward], page 114.	$-2+1$
0171	121	forward-line	1	See [forward-line], page 112.	$-1+1$
0172	122	char-syntax	1	See [char-syntax], page 129.	$-1+1$
0173	123	buffer-substring	1	See [buffer-substring], page 105.	$-2+1$
0174	124	delete-region	1	See [delete-region], page 127.	$-2+1$
0175	125	narrow-to-region	1	See [narrow-to-region], page 115.	$-2+1$
0176	126	widen	1	See [widen], page 116.	$-0+1$
0177	127	end-of-line	1	See [end-of-line], page 128.	$-1+1$

5.3 Opcodes (0200-0277)

Oct	Dec	Instruction	Size	Description	Stack
0201	129	constant2	1	See [constant2], page 30.	+1
0202	130	goto	1	See [goto], page 34.	$-1+0$
0203	131	goto-if-nil	1	See [goto-if-nil], page 35.	$-1+0$
0204	132	goto-if-not-nil	1	See [goto-if-not-nil], page 36.	$-1+0$
0205	133	goto-if-nil-else-pop	1	See [goto-if-nil-else-pop], page 37.	$\phi(-1,0)+0$
0206	134	goto-if-not-nil-else-pop	1	See [goto-if-not-nil-else-pop], page 38.	$\phi(-1,0)+0$
0207	135	return	1	See [return], page 39.	$-1+0$
0210	136	discard	1	See [discard], page 134.	$-1+0$
0211	137	dup	1	See [dup], page 136.	$-0+1$
0212	138	save-excursion	1	See [save-excursion], page 130.	$-0+0$
0213	*139	*save-window-excursion	1	See [save-window-excursion], page 139.	$-1+0$
0214	140			Unused	
0215	141			Unused	
0216	142			Unused	
0217	*143	*condition-case	1	See [condition-case], page 140.	$-1+1$
0220	144	temp-output-buffer-setup	1	See [temp-output-buffer-setup], page 140.	$-1+0$
0221	145	temp-output-buffer-show	1	See [temp-output-buffer-show], page 141.	$-0+0$
0222	146			Unused	
0223	147			Unused	
0256	174			Unused	
0257	175	listN	2	See [listN], page 66.	$-n+1$
0260	176	concatN	2	See [concatN], page 97.	$-n+1$
0261	177	insertN	2	See [insertN], page 118.	$-n+1$
0262	178	stack-set	1	See [stack-set], page 137.	-1
0263	179	stack-set2	1	See [stack-set2], page 138.	-1
0222	*146	*unbind-all	1	See [unbind-all], page 141.	-0
0223	147	set-marker	1	See [set-marker], page 131.	$-3+1$
0224	148	match-beginning	1	See [match-beginning], page 132.	$-1+1$
0225	149	match-end	1	See [match-end], page 133.	$-1+1$
0226	150	upcase	1	See [upcase], page 98.	$-1+1$
0227	151	downcase	1	See [downcase], page 99.	$-1+1$

0230	152	stringeqlsign	1	See [stringeqlsign], page 100.	$-2+1$
0231	153	stringlss	1	See [stringlss], page 101.	$-2+1$
0232	154	equal	1	See [equal], page 53.	$-2+1$
0233	155	nthcdr	1	See [nthcdr], page 70.	$-2+1$
0234	156	elt	1	See [elt], page 71.	$-2+1$
0235	157	member	1	See [member], page 54.	$-2+1$
0236	158	assq	1	See [assq], page 55.	$-2+1$
0237	159	nreverse	1	See [nreverse], page 72.	$-1+1$
0240	160	setcar	1	See [setcar], page 73.	$-2+1$
0241	161	setcdr	1	See [setcdr], page 74.	$-2+1$
0242	162	car-safe	1	See [car-safe], page 75.	$-1+1$
0243	163	cdr-safe	1	See [cdr-safe], page 76.	$-1+1$
0244	164	nconc	1	See [nconc], page 77.	$-2+1$
0245	165	quo	1	See [quo], page 91.	$-2+1$
0246	166	rem	1	See [rem], page 92.	$-2+1$
0247	167	numberp	1	See [numberp], page 56.	$-1+1$
0250	168	integerp	1	See [integerp], page 57.	$-1+1$
0251	169			Unused	
0252	*170	*Rgoto	1	See [Rgoto], page 142.	$-1+0$
0253	*171	*Rgotoifnil	1	See [Rgotoifnil], page 142.	
0254	*172	*Rgotoifnonnil	1	See [Rgotoifnonnil], page 142.	$-1+0$
0255	*173	*Rgotoifnilelsepop	1	See [Rgotoifnilelsepop], page 142.	$\phi(-1,0)+0$
0256	*174	*Rgotoifnonnilelsepop	1	See [Rgotoifnonnilelsepop], page 142,	$\phi(-1,0)+0$
0257	175	listN	2	See [listN], page 66.	$-n+1$
0260	176	concatN	2	See [concatN], page 97.	
0261	177	insertN	1	See [insertN], page 118.	$-n+1$
0262	178	stack-set	1	See [stack-set], page 137.	$-0+0$
0263	179	stack-set2	2	See [stack-set2], page 138.	$-0+0$
0264	180			Unused	
0265	181			Unused	
0266	182	discardN	1	See [discardN], page 135.	$-n+0$
0267	183	switch	1	See [switch], page 40.	$-2+0$
0270	184			Unused	
0271	185			Unused	
0272	186			Unused	
0273	187			Unused	
0274	188			Unused	
0275	189			Unused	
0276	190			Unused	
0277	191			Unused	

5.4 Opcodes (0300-3277) Constants

Oct	Dec	Instruction	Size	Description	Stack
0300	192	`constant[0]`	1	See [constant], page 29.	+1
0301	193	`constant[1]`	1	See [constant], page 29.	+1
0302	194	`constant[2]`	1	See [constant], page 29.	+1
0303	195	`constant[3]`	1	See [constant], page 29.	+1
0304	196	`constant[4]`	1	See [constant], page 29.	+1
0305	197	`constant[5]`	1	See [constant], page 29.	+1
0306	198	`constant[6]`	1	See [constant], page 29.	+1
0307	199	`constant[7]`	1	See [constant], page 29.	+1
0310	200	`constant[8]`	1	See [constant], page 29.	+1
0311	201	`constant[9]`	1	See [constant], page 29.	+1
0312	202	`constant[10]`	1	See [constant], page 29.	+1
0313	203	`constant[11]`	1	See [constant], page 29.	+1
0314	204	`constant[12]`	1	See [constant], page 29.	+1
0315	205	`constant[13]`	1	See [constant], page 29.	+1
0316	206	`constant[14]`	1	See [constant], page 29.	+1
0317	207	`constant[15]`	1	See [constant], page 29.	+1
0320	208	`constant[16]`	1	See [constant], page 29.	+1
0321	209	`constant[17]`	1	See [constant], page 29.	+1
0322	210	`constant[18]`	1	See [constant], page 29.	+1
0323	211	`constant[19]`	1	See [constant], page 29.	+1
0324	212	`constant[20]`	1	See [constant], page 29.	+1
0325	213	`constant[21]`	1	See [constant], page 29.	+1
0326	214	`constant[22]`	1	See [constant], page 29.	+1
0327	215	`constant[23]`	1	See [constant], page 29.	+1
0330	216	`constant[24]`	1	See [constant], page 29.	+1
0331	217	`constant[25]`	1	See [constant], page 29.	+1
0332	218	`constant[26]`	1	See [constant], page 29.	+1
0333	219	`constant[27]`	1	See [constant], page 29.	+1
0334	220	`constant[28]`	1	See [constant], page 29.	+1
0335	221	`constant[29]`	1	See [constant], page 29.	+1
0336	222	`constant[30]`	1	See [constant], page 29.	+1
0337	223	`constant[31]`	1	See [constant], page 29.	+1
0340	224	`constant[32]`	1	See [constant], page 29.	+1
0341	225	`constant[33]`	1	See [constant], page 29.	+1
0342	226	`constant[34]`	1	See [constant], page 29.	+1
0343	227	`constant[35]`	1	See [constant], page 29.	+1
0344	228	`constant[36]`	1	See [constant], page 29.	+1
0345	229	`constant[37]`	1	See [constant], page 29.	+1
0346	230	`constant[38]`	1	See [constant], page 29.	+1
0347	231	`constant[39]`	1	See [constant], page 29.	+1
0350	232	`constant[40]`	1	See [constant], page 29.	+1
0351	233	`constant[41]`	1	See [constant], page 29.	+1

0352	234	`constant[42]`	1	See [constant], page 29.	+1
0353	235	`constant[43]`	1	See [constant], page 29.	+1
0354	236	`constant[44]`	1	See [constant], page 29.	+1
0355	237	`constant[45]`	1	See [constant], page 29.	+1
0356	238	`constant[46]`	1	See [constant], page 29.	+1
0357	239	`constant[47]`	1	See [constant], page 29.	+1
0360	240	`constant[48]`	1	See [constant], page 29.	+1
0361	241	`constant[49]`	1	See [constant], page 29.	+1
0362	242	`constant[50]`	1	See [constant], page 29.	+1
0363	243	`constant[51]`	1	See [constant], page 29.	+1
0364	244	`constant[52]`	1	See [constant], page 29.	+1
0365	245	`constant[53]`	1	See [constant], page 29.	+1
0366	246	`constant[54]`	1	See [constant], page 29.	+1
0367	247	`constant[55]`	1	See [constant], page 29.	+1
0370	248	`constant[56]`	1	See [constant], page 29.	+1
0371	249	`constant[57]`	1	See [constant], page 29.	+1
0372	250	`constant[58]`	1	See [constant], page 29.	+1
0373	251	`constant[59]`	1	See [constant], page 29.	+1
0374	252	`constant[60]`	1	See [constant], page 29.	+1
0375	253	`constant[61]`	1	See [constant], page 29.	+1
0376	254	`constant[62]`	1	See [constant], page 29.	+1
0377	255	`constant[63]`	1	See [constant], page 29.	+1

6 References

- Execution of byte code produced by bytecomp.el (http://git.savannah.gnu.org/cgit/emacs.git/tree/src/bytecode.c)
- bytecomp.el — compilation of Lisp code into byte code (http://git.savannah.gnu.org/cgit/emacs.git/tree/lisp/emacs-lisp/bytecomp.el)
- data.c — Primitive operations on Lisp data types (http://git.savannah.gnu.org/cgit/emacs.git/tree/src/data.c)
- Emacs Byte-code Internals (http://nullprogram.com/blog/2014/01/04/)
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- Emacs Lisp Decompiler (https://github.com/rocky/elisp-decompile)
- GNU Emacs Lisp Reference Manual (https://ftp.gnu.org/pub/gnu/emacs)
- GNU Emacs source code since Emacs 21.4a (https://ftp.gnu.org/pub/gnu/emacs)
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- GNU Emacs source code before Emacs 21.4a (https://ftp.gnu.org/pub/old-gnu/emacs)

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