PerlGuts Illustrated

Version 0.40, for perl 5.16 and older

This document is meant to supplement the *perlguts(1)* manual page that comes with Perl. It contains commented illustrations of all major internal Perl data structures. Having this document handy hopefully makes reading the Perl source code easier. It might also help you interpret the *Devel::Peek* dumps.

Most of the internal perl structures had been refactored twice, with 5.10, and 5.14. The comparison links and illustrations for 5.8, 5.10, 5.14 and 5.16 are available as extra files. 5.10 to 5.12 changes: only *OOK*.

- illguts for 5.8 and older
- illguts for 5.10
- illguts for 5.12
- illguts for 5.14 + 5.16

The first things to look at are the data structures that represent Perl data; scalars of various kinds, arrays and hashes. Internally Perl calls a scalar *SV* (scalar value), an array *AV* (array value) and a hash *HV* (hash value). In addition it uses *IV* for integer value, *NV* for numeric value (aka double), *PV* for a pointer value (aka string value (char*), but 'S' was already taken), and *RV* for reference value. The *IVs* are further guaranteed to be big enough to hold a `void*` pointer.

The internal relationship between the Perl data types is really object oriented. Perl relies on using C's structural equivalence to help emulate something like C++ inheritance of types. The various data types that Perl implement are illustrated in this class hierarchy diagram. The arrows indicate inheritance (IS-A relationships).

As you can see, Perl uses multiple inheritance with *SvNULL* (also named just *SV*) acting as some kind of virtual base class. All the Perl types are identified by small numbers, and the internal Perl code often gets away with testing the ISA-relationship between types with the <= operator. As you can see from the figure above, this can only work reliably for some comparisons. All Perl data value objects are tagged with their type, so you can always ask an object what its type is and act according to this information.

The symbolic **SvTYPE** names (and associated value) are with 5.14:

svtype	5.14 + 5.16	5.10	5.6 + 5.8
0	**SVt_NULL**	SVt_NULL	SVt_NULL
1	**SVt_BIND**	SVt_BIND	SVt_IV
2	**SVt_IV**	SVt_IV	SVt_NV
3	**SVt_NV**	SVt_NV	SVt_RV
4	**SVt_PV**	SVt_RV	SVt_PV
5	**SVt_PVIV**	SVt_PV	SVt_PVIV
6	**SVt_PVNV**	SVt_PVIV	SVt_PVNV
7	**SVt_PVMG**	SVt_PVNV	SVt_PVMG
8	**SVt_REGEXP**	SVt_PVMG	SVt_PVBM
9	**SVt_PVGV**	SVt_PVGV	SVt_PVLV
10	**SVt_PVLV**	SVt_PVLV	SVt_PVAV
11	**SVt_PVAV**	SVt_PVAV	SVt_PVHV
12	**SVt_PVHV**	SVt_PVHV	SVt_PVCV
13	**SVt_PVCV**	SVt_PVCV	SVt_PVGV
14	**SVt_PVFM**	SVt_PVFM	SVt_PVFM
15	**SVt_PVIO**	SVt_PVIO	SVt_PVIO

In addition to the simple type names already mentioned, the following names are found in the hierarchy figure: An *PVIV* value can hold a string and an integer value. An *PVNV* value can hold a string, an integer and a double value. The *PVMG* is used when magic is attached or the value is blessed. The *PVLV* represents a LValue object. *RV* is now a seperate scalar of type *SVt_IV*. *CV* is a code value, which represents a perl function/subroutine/closure or contains a pointer to an XSUB. *GV* is a glob value and *IO* contains pointers to open files and directories and various state information about these. The *PVFM* is used to hold information on forms. *P5RX* was formerly called *PVBM* for Boyer-Moore (match information), but contains now more information. *BIND* is a placeholder for read-only aliases or VIEW, and implemented as *RV* for now. (#29544, #29642)

A Perl data object can change type as the value is modified. The SV is said to be upgraded in this case. Type changes only go down the hierarchy. (See the sv_upgrade() function in `sv.c`.)

The actual layout in memory does not really match how a typical C++ compiler would implement a hierarchy like the one depicted above. Let's see how it is done.

> *In the description below we use field names that match the macros that are used to access the corresponding field. For instance the `xpv_cur` field of the `xpvXX` structs are accessed with the `SvCUR()` macro. The field is referred to as **CUR** in the description below. This also match the field names reported by the Devel::Peek module.*

_SV_HEAD and struct sv

The simplest type is the "struct sv". It represents the common structure for a SV, GV, CV, AV, HV, IO and P5RX, without any struct xpv<*xx*> attached to it. It consist of four words, the _SV_HEAD with 3 values and the SV_U union with one pointer.

_SV_HEAD and SV_U union

The first word contains the **ANY** pointer to the optional body. All types are implemented by attaching additional data to the ANY pointer, just the RV not.

The second word is an 32 bit unsigned integer reference counter (**REFCNT**) which should tell us how many pointers reference this object. When Perl data types are created this value is initialized to 1. The field must be incremented when a new pointer is made to point to it and decremented when the pointer is destroyed or assigned a different value. When the reference count reaches zero the object is freed.

The third word contains a **FLAGS** field and a **TYPE** field as 32 bit unsigned integer.

Since 5.10 the forth and last word contains the **sv_u union**, which contains a pointer to another SV (a RV), the PV string, the AV svu_array, a HE hash or a GP struct. The TYPE field contains a small number (0-127, mask `0xff`) that represents one of the `SVt_` types shown in the type hierarchy figure above. The FLAGS field has room for 24 flag bits (`0x00000100-0x80000000`), which encode how various fields of the object should be interpreted, and other state information. Some flags are just used as optimizations in order to avoid having to dereference several levels of pointers just to find that the information is not there.

The purpose of the **SvFLAGS** bits are:

0x00000100 **SVf_IOK** (public integer)
: This flag indicates that the object has a valid public IVX field value. It can only be set for value type SvIV or subtypes of it.

0x00000200 **SVf_NOK** (public number)
: This flag indicates that the object has a valid public NVX field value. It can only be set for value type SvNV or subtypes of it.

0x00000400 **SVf_POK** (public string)
: This flag indicates that the object has a valid public PVX, CUR and LEN field values (i.e. a valid string value). It can only be set for value type SvPV or subtypes of it.

0x00000800 **SVf_ROK** (valid reference pointer)
: This flag indicates that the type should be treated as an SvRV and that the RV field contains a valid reference pointer.

0x00001000 **SVp_IOK** (private integer)

This flag indicates that the object has a valid non-public IVX field value. It can only be set for value type SvIV or subtypes of it.

The private OK flags (SVp_IOK, SVp_NOK, SVp_POK) are used by the magic system. During execution of a magic callback, the private flags will be used to set the public flags. When the callback returns, then the public flags are cleared. This effectively is used to pass the value to get/set to/from magic callbacks.

0x00002000 **SVp_NOK** (private number)
: This flag indicates that the object has a valid non-public NVX field value, a double float. It can only be set for value type SvNV or subtypes of it.

0x00004000 **SVp_POK** (private string)
: This flag indicates that the object has a valid non-public PVX, CUR and LEN field values (i.e. a valid string value). It can only be set for value type SvPV or subtypes of it.

0x00008000 **SVp_SCREAM**
: A string SvPV* type has been studied.

0x00008000 **SVphv_CLONEABLE**
: PVHV (stashes) clone its objects.

0x00008000 **SVpgv_GP**
: GV has a valid GP.

0x00008000 **SVprv_PCS_IMPORTED**
: RV is a proxy for a constant subroutine in another package. Set the CvIMPORTED_CV_ON() if it needs to be expanded to a real GV.

0x00010000 **SVs_PADSTALE**
: lexical has gone out of scope

0x00010000 **SVpad_STATE**
: pad name is a "state" var

0x00020000 **SVs_PADTMP**
: in use as tmp

0x00020000 **SVpad_TYPED**
: pad name is a typed Lexical

0x00040000 **SVs_PADMY**
: in use a "my" variable

0x00040000 **SVpad_OUR**
: pad name is "our" instead of "my"

0x00080000 **SVs_TEMP**
: string is stealable

0x00100000 **SVs_OBJECT**
: This flag is set when the object is "blessed". It can only be set for value type SvPVMG or subtypes of it. This flag also indicates that the STASH pointer is valid and points to a namespace HV.

0x00200000 **SVs_GMG** (Get Magic)
: This flag indicates that the object has a magic *get* or *len* method to be invoked. It can only be set for value type SvPVMG or subtypes of it. This flag also indicate that the MAGIC pointer is valid. Formerly called GMAGICAL.

0x00400000 **SVs_SMG** (Set Magic)
: This flag indicates that the object has a magic *set* method to be invoked. Formerly called SMAGICAL.

0x00800000 **SVs_RMG** (Random Magic)
: This flag indicates that the object has any other magical methods (besides get/len/set magic method) or even methodless magic attached.

The SVs_RMG flag (formerly called RMAGICAL) is used mainly for tied HV and AV (having 'P' magic) and SVs which have magic *clear* method. It is used as an optimization to avoid setting SVs_GMG and SVs_SMG flags for SVs which need to be marked as MAGICAL otherwise.

Any of SVs_GMG, SVs_SMG and SVs_RMG is called MAGICAL

0x01000000 **SVf_FAKE**
: 0: glob or lexical is just a copy
: 1: SV head arena wasn't malloc()ed
: 2: in conjunction with SVf_READONLY marks a shared hash key scalar (SvLEN == 0) or a copy on write string (SvLEN != 0) [SvIsCOW(sv)]
: 3: For PVCV, whether CvUNIQUE(cv) refers to an eval or once only [CvEVAL(cv), CvSPECIAL(cv)]
: 4: On a pad name SV, that slot in the frame AV is a REFCNT'ed reference to a lexical from "outside"

0x01000000 **SVphv_REHASH**
: 5: On a PVHV, hash values are being recalculated

0x02000000 **SVf_OOK** (Offset OK)
: For a PVHV this means that a hv_aux struct is present after the main array. This flag indicates that the string has an offset at the beginning. This flag can only be set for value type SvPVIV or subtypes of it. It also follows that the IOK (and IOKp) flag must be off when OOK is on. Take a look at the *SvOOK* figure below.

0x04000000 **SVf_BREAK**
: REFCNT is artificially low. Used by SVs in final arena cleanup. Set in S_regtry on PL_reg_curpm, so that perl_destruct() will skip it

0x08000000 **SVf_READONLY**
: This flag indicate that the value of the object may not be modified.

0x10000000 **SVf_AMAGIC**
: has magical overloaded methods

0x20000000 **SVphv_SHAREKEYS**
: Only used by HVs. See description of HV below.

0x20000000 **SVf_UTF8**
: SvPV is UTF-8 encoded. This is also set on RVs whose overloaded stringification is UTF-8. This might only happen as a side effect of SvPV().

0x40000000 **SVpav_REAL**
: Free old entries in AVs only. See description of AV below.

0x40000000 **SVphv_LAZYDEL**
: Only used by HVs. This is only set true on a PVGV when it's playing "PVBM", but is tested for on any regular scalar (anything <= PVLV). See description of HV below.

0x40000000 **SVpbm_VALID**
: Unused. See description of PVBM below.

0x40000000 **SVrepl_EVAL**
: Replacement part of s///e

0x80000000 **SVf_IVisUV**
: Use XPVUV instead of XPVIV. For IVs only (IV, PVIV, PVNV, PVMG, PVGV and maybe PVLV).

0x80000000 **SVpav_REIFY**
: Can become real. For PVAV only.

0x80000000 **SVphv_HASKFLAGS**
: Keys have flag byte after hash. For PVHV only.

0x80000000 **SVpfm_COMPILED**

FORMLINE is compiled. For PVFM only.

0x80000000 **SVpbm_TAIL**

PVGV when SVpbm_VALID is true. Only used by SvPVBMs. See description of PVBM below.

0x80000000 **SVprv_WEAKREF**

RV upwards. However, SVf_ROK and SVp_IOK are exclusive. For RV only.

The `struct sv` is common for all variable types in Perl. In the Perl source code this structure is typedefed to *SV*, *RV*, *AV*, *HV*, *CV*, *GV*, *IO* and *P5RX*. Routines that can take any type as parameter will have `SV*` as parameter. Routines that only work with arrays or hashes have `AV*` or `HV*` respectively in their parameter list. Likewise for the rest.

SvPV

A scalar that can hold a string value is called an *SvPV*. In addition to the *SV* struct of SvNULL, an *xpv* struct is allocated and it contains 3-4 fields. **svu_pv** was formerly called **PVX** and before 5.10 it was the first field of xpv. svu_pv/PVX is the pointer to an allocated char array. All old field names **must** be accessed through the old macros, which is called SvPVX(). **CUR** is an integer giving the current length of the string. **LEN** is an integer giving the length of the allocated string. The byte at (PVX + CUR) should always be '\0' in order to make sure that the string is NUL-terminated if passed to C library routines. This requires that LEN is always at least 1 larger than CUR.

The **POK** flag indicates that the string pointed to by PVX contains an valid string value. If the POK flag is off and the ROK flag is turned on, then the PVX field is used as a pointer to an RV (see SvRV below) and the struct xpv is unused. An SvPV with both the POK and ROK flags turned off represents *undef*. The PVX pointer can also be NULL when POK is off and no string storage has been allocated.

SvPVIV and SvPVNV

The *SvPVIV* type is like *SvPV* but has an additional field to hold a single integer value called **IVX** in **xiv_u**. The **IOK** flag indicates if the IVX value is valid. If both the IOK and POK flag is on, then the PVX will (usually) be a string representation of the same number found in IVX.

The *SvPVNV* type is like *SvPVIV* but uses the single *double* value called NVX in xnv_u. The corresponding flag is called NOK.

SvOOK

As a special hack, in order to improve the speed of removing characters from the beginning of a string, the *OOK flag* is used. *SvOOK_offset* used to be stored in SvIVX, but is since 5.12 stored within the first 8 bit (one char) of the buffer. The PVX, CUR, LEN is adjusted to point within the allocated string instead.

SvIV and SvNV

SvIVX uses the xiv_u .xiv_iv slot in the xiv_u union (don't be fooled by the convenience shortcut xiv_iv), *SvNVX* uses the xnv_u.xnv_nv slot in the xnv_u union.

SvRV

The *SvRV* type uses the fourth word sv_u.svu_rv as pointer to an SV (which can be any of the SvNULL subtypes), AV or HV. A SvRV object with ROK flag off represents an undefined value.

SvPVMG

Blessed scalars or other magic attached. *SvPVMG* has two additional fields; MAGIC and STASH. MAGIC is a pointer to additional structures that contains callback functions and other data. If the MAGIC pointer is non-NULL, then one or more of the MAGICAL flags will be set.

STASH (**s**ymbol **t**able h**ash**) is a pointer to a HV that represents some namespace/class. (That the HV represents some namespace means that the NAME field of the HV must be non-NULL. See description of HVs and stashes below). The STASH field is set when the value is blessed into a package (becomes an object). The OBJECT flag will be set when STASH is. *(IMHO, this field should really have been named "CLASS". The GV and CV subclasses introduce their own unrelated fields called STASH which might be confusing.)*

The field MAGIC points to an instance of `struct magic` (typedef'ed as `MAGIC`). This struct has 8 fields:

1. *moremagic* is a pointer to another MAGIC and is used to form a single linked list of the MAGICs attached to an SV.
2. *virtual* is a pointer to a struct containing 5-8 function pointers. The functions (if set) are invoked when the corresponding action happens to the SV.
3. *private* is a 16 bit number (U16) not used by Perl.
4. *type* is a character field and is used to denote which kind of magic this is. The interpretation of the rest of the fields depend on the *type* (actually it is the callbacks attached to *virtual* that do any interpretation). There is usually a direct correspondence between the *type* field and the *virtual* field.
5. *flags* contains 8 flag bits, where 2 of them are generally used. Bit 2 is the **REFCOUNTED** flag. It indicates that the *obj* is assumed to be an SV and that it's reference count must be decremented when this magic is freed. Self-referenced magic obj <=> sv have the REFCOUNTED flag not set, so that on destruction no self-ref'ed loops can appear. The **GSKIP** flag indicate that invocation of the magical GET method should be suppressed. Other flag bits are used depending of the kind of magic.
6. *obj* is usually a pointer to some SV, *SvTIED_obj*. How it is used depends on the kind of magic this is.
7. *ptr* is usually a pointer to some character *MgPV* string. How it is used depends on the kind of magic this is. If the *len* field is >= 0, then *ptr* is assumed to point to a malloced buffer and will be automatically freed when the magic is.
8. *len* is usually the length of the character string pointed to by *ptr*. How it is used depends on the kind of magic this is.

The `struct magic_state` is stored on the global savestack. *mgs_sv* points to our magical sv, and *mgs_ss_ix* points on the savestack after the saved destructor.

SvPVBM (old)

Since 5.10 *SvPVBM* are really *PVGV*s, with the **VALID** flag set, and "B" magic attached. Before *SvPVBM* where *SV* objects by their own.

The *SvPVBM* is like SvPVMG above. I uses the `xnv_u` union for three additional values in `xbm_s`; `U32 BmPREVIOUS, U8 BmUSEFUL, U8 BmRARE`. The SvPVBM value types are used internally to implement very fast lookup of the string in PVX using the "Boyer-Moore" algorithm. They are used by the Perl `index()` builtin when the search string is a constant, as well as in the RE engine. The `fbm_compile()` function turns normal SvPVs into this value type.

A table of 256 elements is appended to the PVX. This table contains the distance from the end of string of the last occurrence of each character in the original string. (In recent Perls, the table is not built for strings shorter than 3 character.) In addition fbm_compile() locates the rarest character in the string (using builtin letter frequency tables) and stores this character in the *BmRARE* field. The *BmPREVIOUS* field is set to the location of the first occurrence of the rare character. *BmUSEFUL* is incremented (decremented) by the RE engine when this constant substring (does not) help in optimizing RE engine access away. If it goes below 0, then the corresponding substring is forgotten and freed;

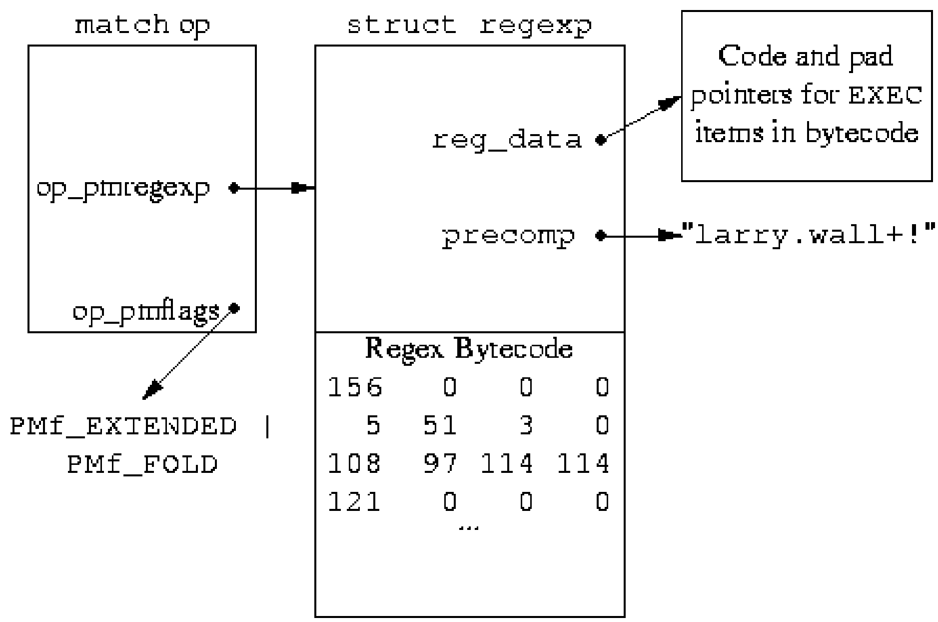
The extra SvPVBM information and the character distance table is only valid when the **VALID** flag is on. A magic structure with the sole purpose of turning off the VALID flag on assignment, is always attached to a *valid* SvPVBM.

The **TAIL** flag is used to indicate that the search for the SvPVMG should be *tail anchored*, i.e. a match should only be considered at the end of the string (or before newline at the end of the string).

REGEXP (P5RX)

The structures behind the P5RX, the *struct regexp*, store the compiled and optimized state of a perl regular expression. New here is support for pluggable regex engines - the original engine was critized *("Thompson NFA for abnormal expressions would be linear, but does not support backtracking")*, non-recursive execution, and faster trie-structures for alternations. See re::engine::RE2 for the fast DFA implementation without backrefs.

The *struct regexp* contains the compiled bytecode of the expression, some meta-information about the regex, such as the used engine, the precomp and the number of pairs of backreference parentheses. *reg_data* contains code and pad pointers for EXEC items in the bytecode.



Marc Jason Dominus - http://perl.plover.com/Rx/paper/

Nobody so far did a successful freeze/thaw of those internal structures, but we have Abhijit's `re_dup()` to clone a regexp, and we can simply recompile along

```
PM_SETRE(&pm, CALLREGCOMP(newSVpv($restring), $op->pmflags));
RX_EXTFLAGS(PM_GETRE(&pm)) = $op->reflags;
```

Marc-Jason Dominus implemented a debugger for the compiled Rx bytecode http://perl.plover.com/Rx/paper/.

See **perlreguts** for some details.

SvPVLV

The *SvPVLV* is like *SvPVMG* above, but has four additional fields; TARGOFF, TARGLEN, TARG, TYPE. The typical use is for Perl builtins that can be used in the LValue context (substr, vec,...). They will return an SvPVLV value, which when assigned to use magic to affect the *target* object, which they keep a pointer to in the TARG field. The xiv_u union is used as the GvNAME field, pointing to a namehek.

The TYPE is a character variable. It encodes the kind if LValue this is. Interpretation of the other LValue fields depend on the TYPE. The SvPVLVs are (almost) always magical. The magic type will match the TYPE field of the SvPVLV. The types are:

'x'
: Type-x LVs are returned by the `substr($string, $offset, $len)` builtin.

'v'
: Type-v LVs are returned by the `vec($string, $offset, $bits)` builtin.

'.'
: Type-. LVs are returned by the `pos($scalar)` builtin.

'k'
: Type-k LVs are returned when `keys %hash` is used on the left side of the assignment operator.

'y'
: Type-y LVs are used by auto-vivification (of hash and array elements) and the foreach array iterator variable.

'/'
: Used by *pp_pushre*. *(I don't understand this yet.)*

The figure below shows an SvPVLV as returned from the `substr()` builtin. The first substr parameter (the string to be affected) is assigned to the TARG field. The substr offset value goes in the TARGOFF field and the substr length parameter goes in the TARGLEN field.

When assignment to an SvPVLV type occurs, then the value to be assigned is first copied into the SvPVLV itself (and affects the PVX, IVX or NVX). After this the magic SET method is invoked, which will update the TARG accordingly.

AV

An array is in many ways represented similar to strings. An AV contains all the fields of SvPVMG, but not more. Some fields of xpvav and sv have been renamed. ARYLEN uses the MAGIC field, to point to a magic SV (which is returned when `$#array` is requested) and is only created on demand. IVX has become ALLOC, which is a pointer to the allocated array. PVX in the sv_u has become ARRAY, the direct pointer the the current array start, CUR has become FILL and LEN has become MAX. One difference is that the value of

FILL/MAX is always one less than CUR/LEN would be in a SVPV. The NVX field is unused.

The previous extra FLAGS field in the xpvav has been merged into the sv_flags field.

The array pointed to by ARRAY contains pointers to any of the SvNULL subtypes. Usually ALLOC and ARRAY both point to the start of the allocated array. The use of two pointers is similar to the OOK hack described above. The shift operation can be implemented efficiently by just adjusting the ARRAY pointer (and FILL/MAX). Similarly, the pop just involves decrementing the FILL count.

There are only 2 array flags defined:

SVpav_REAL
: It basically means that all SVs contained in this array is owned and must have their reference counters decremented when the reference is removed from the array. All normal arrays are REAL. For the `stack` the REAL flag is turned off. For `@_` the REAL flag is initially turned off.

SVpav_REIFY
: The array is *not* REAL but should be made REAL if modified. The `@_` array will have the REIFY flag turned on.

HV

Hashes are the most complex of the Perl data types. In addition to what we have seen above, the very last index in the HE*[] points to a new xpvhv_aux struct. HVs use *HE* structs to represent "hash element" key/value pairs and *HEK* structs to represent "hash element keys".

RITER, EITER:
: Those two fields are used to implement a single iterator over the elements in the hash. RITER which is an integer index into the array referenced by ARRAY and EITER which is a pointer to an HE. In order find the next hash element one would first look at EITER->next and if it turns out to be NULL, RITER is incremented until ARRAY[RITER] is non-NULL. The iterator starts out with RITER = -1 and EITER = NULL.

NAME:
: Until 5.14 NAME was a NUL-terminated string which denotes the fully qualified name of the name space (aka *package*). This was one of the few places where Perl does not allow strings with embedded

NULs. Since 5.14 the value of NAME points to a HEK if name_count == 0, or to two HEKs, where HEK[0] is the effective stash name (HvENAME_HEK_NN) if name_count > 0 or HEK[1] if name_count < 0.

GvSTASH (until 5.8):
: When the hash represented a name space (*stash*) GvSTASH (formerly called PMROOT) pointed to a node in the Perl syntax tree. It was used to implement the reset() builtin for REs.

The first few fields of the xpvhv have been renamed in the same way as for AVs. **MAX** is the number of elements in ARRAY minus one. (The size of the ARRAY is required to be a power of 2, since the code that deals with hashes just mask off the last few bits of the HASH value to locate the correct HE column for a key: `ARRAY[HASH & MAX]`). Also note that ARRAY can be NULL when the hash is empty (but the MAX value will still be at least 7, which is the minimum value assigned by Perl.)
The **FILL** is the number of elements in ARRAY which are not NULL. The IVX field has been renamed **KEYS** and is the number of hash elements in the HASH.

The **HE**s are simple structs containing 3 pointers. A pointer to the next HE, a pointer to the key and a pointer to the value of the given hash element.

The **HEK**s are special variable sized structures that store the hash keys. They contain 4 fields. The computed *hash* value of the string, the *len*gth of the string, *len*+1 bytes for the key string itself (including trailing NUL), and a trailing byte for HEK_FLAGS *(since 5.8)*. As a special case, a *len* value of `HEf_SVKEY` (-2) indicate that a pointer to an SV is stored in the HEK instead of a string. This hack is used for some magical hashes.

In a perfect hash both KEYS and FILL are the same value. This means than all HEs can be located directly from the pointer in the ARRAY (and all the he->next pointers are NULL).

The following two hash specific flags are found among the common SvNULL flags:

0x20000000 **SVphv_SHAREKEYS**
: When this flag is set, then the hash will share the HEK structures with a special hash pointed to by the `strtab` variable. This reduce the storage occupied by hash keys,

especially when we have lots of hashes with the same keys. The SHAREKEYS flag is on by default for newly created HVs.

What is special with the `strtab` hash is that the *val* field of the HE structs is used as a reference counter for the HEK. The counter is incremented when new hashes link up this HEK and decremented when the key is removed from the hashes. When the reference count reach 0, the HEK (and corresponding HE) is removed from `strtab` and the storage is freed.

0x40000000 **SVphv_LAZYDEL**

This flag indicates that the hash element pointed to by EITER is really deleted. When you delete the current hash element, perl only marks the HV with the LAZYDEL flag, and when the iterator is advanced, then the element is zapped. This makes it possible to delete elements in a hash while iterating over it.

GV

GV ("glob value" aka "symbol") shares the same structure as the *SvPVMG*.

The GP is a pointer to structure that holds pointers to data of various kinds. Perl use a pointer, instead of including the GP fields in the xpvgv, in order to implement the proper glob aliasing behavior (i.e. different GVs can share the same GP).

The NAMEHEK denotes the unqualified name of this symbol and GvSTASH points to the symbol table where this symbol belongs. The fully qualified symbol name is obtained by taking the NAME of the GvSTASH (see HV above) and appending "::" and NAME to it. The hash pointed to by GvSTASH will usually contain an element with NAME as key and a pointer to this GV as value. See description of stashes below.

A magic of type '*' is always attached to the GV (not shown in the figure). The magic GET method is used to stringify the globs (as the fully qualified name prefixed with '*'). The magic SET method is used to alias an GLOB based on the name of another glob.

GvFLAGS:

0x1) **INTRO**
0x2) **MULTI**
Have we seen more than one occurrence of this glob. Used to implement the "possibly typo" warning.
0x4) **ASSUMECV** The GV is most likely a CV.
0x8) **IN_PAD** With ithreads new GVs are created temporary on the PAD, and not as global SV.
0x10) **IMPORTED_SV**
0x20) **IMPORTED_AV**
0x40) **IMPORTED_HV**
0x80) **IMPORTED_CV**

GP

GPs can be shared between one or more GVs. The data type fields for the GP are: SV, IO, FORM, AV, HV, CV. These hold a pointer to the corresponding data type object. (The SV must point to some simple SvNULL subtype (i.e. with type <= SVt_PVLV). The FORM field must point to a SvPVFM if non-NULL. The IO field must point to an IO if non-NULL, the AV to an AV, etc.) The SV is always present (but might point to a SvNULL object). All the others are initially NULL.

The additional administrative fields in the GP are: CVGEN, REFCNT, EGV, LINE, FILE_HEK.

REFCNT is a reference counter. It says how many GVs have a pointer to this GP. It is incremented/decremented as new GVs reference/forget this GP. When the counter reach 0 the GP is freed.

EGV, the "effective gv", if *glob, is a pointer to the GV that originally created this GP (used to tell the real name of any aliased symbol). If the original GV is freed, but GP should stay since another GV reference it, then the EGV is NULLed.

CVGEN is an integer used to validate method cache CV entries in the GP. If CVGEN is zero, then the CV is real. If CVGEN is non-zero, but less than the global variable `subgeneration`, then the CV contains a stale method cache entry. If CVGEN is equal to `subgeneration` then the CV contains a valid method cache entry.
Every time some operation that might invalidate some of the method caches are performed, then the `subgeneration` variable is incremented.

FILE_HEK is the name of the file where this symbol was first created.

LINE is the corresponding line number in the file.

Stashes

GVs and stashes work together to implement the name spaces of Perl. Stashes are named HVs with all the element values being pointers to GVs. The root of the namespace is pointed to by the global variable `defstash`.

In the figure below we have simplified the representation of stashes to a single box. The text in the blue field is the NAME of the HV/stash. The hash elements keys are shown as field names and the element values are shown as a pointers to globs (GV). The GVs are also simplified to a single box. The text in the green field in the fully qualified name of the GV. Only the GP data fields are shown (and FORM has been eliminated because it was not 2 letters long :-).

The figure illustrates how the scalar variables `$::foo` and `$foo::bar::baz` are represented by Perl.

All resolution of qualified names starts with the stash pointed to by the `defstash` variable. Nested name spaces are implemented by a stash entry with a key ending in "`::`". The entry for "`main::`" ensures that `defstash` is also known as "`main`" package (and has the side-effect that the "`main::main::main`" package is `defstash` too.) Unqualified names are resolved starting at `curstash` or `curcop->cop_stash` which are influenced by the `package` declaration in Perl.

As you can see from this figure, there are lots of pointers to dereference in order to look up deeply nested names. Each stash is at least 4 levels deep and each glob is 3 levels, giving at least 24 pointer dereferences to access the data in the `$foo::bar::baz` variable from `defstash`.

The `defstash` stash is also a place where globs representing source files are entered. These entries are prefixed with "_<". The FILEGV field of the GP points to the same glob as the corresponding "_<" entry in `defstash` does.

CV

The *CV* ("code value") is like *SvPVMG* above, but has some renamed and additional fields; CvSTASH, START, ROOT, GV, FILE, DEPTH, PADLIST, OUTSIDE, OUTSIDE_SEQ, CvFLAGS.

The `CvSTASH` is a pointer to the stash in which the CV was *compiled*.

`START` and `ROOT` point to the start and the root of the compiled op tree for this function.

DEPTH and PADLIST are needed to access and check the current scratchpad. Lexicals are accessed by the OP->targ index into the PADLIST.

See PADs and OPs below.

SvPVFM

The *SvPVFM* is like *CV* above, but adds a single field called LINES.

IO

The *IO* is like *SvPVMG* above, but has quite a few additional fields.

IoFLAGS

1 IOf_ARGV this fp iterates over ARGV
2 IOf_START check for null ARGV and substitute '-'
4 IOf_FLUSH this fp wants a flush after write op
8 IOf_DIDTOP just did top of form
16 IOf_UNTAINT consider this fp (and its data) "safe"
32 IOf_NOLINE slurped a pseudo-line from empty file
64 IOf_FAKE_DIRP xio_dirp is fake (source filters kludge)

PAD

A `PAD` is a list (AV) of elements for Perl variables for each subroutine. PADs ("Scratchpads") are used by Perl to store lexical variables, op targets and constants. Every `TARG` argument for on OP (see below) is a index into the `PAD`, and each recursion level has its own `PAD`.

Each new sub creates a PADLIST of length 1, which points to current PAD, the PL_curpad, indexed by TARG. The 0'th entry of the CvPADLIST is an AV which represents the "names" or rather the "static type information" for lexicals. The CvDEPTH'th entry of CvPADLIST AV is an AV which is the stack frame at that depth of recursion into the CV. The 0'th slot of a frame AV is an AV which is @_. Other entries are storage for variables and op targets, the scratchpads. During compilation is simplified scratchpad is used. The current PL_comppad is just a PAD which holds the TARG variables directly, without indirection which is needed for run-time recursion and threading. During compilation: PL_comppad_name is set to the names AV, the declared type information. PL_comppad is set to the frame AV for the frame CvDEPTH == 1. PL_curpad is set to the body of the frame AV (i.e. AvARRAY(PL_comppad)).
During execution, PL_comppad and PL_curpad refer to the live frame of the currently executing sub.

Lexicals (my and our variables) have SVs_PADMY / SVs_PADOUR set, and targets have SVs_PADTMP set. A SVs_PADTMP (targets/GVs/constants) has a &PL_sv_undef name, as they are looked up by the TARG index, only SVs_PADMY / SVs_PADOUR get valid names.

OP

A Perl program/subroutine is represented internally by a syntax tree built from OP nodes. This tree really is just a linked list of ops in *exec* order. Perl 5.005 had 346 different OP-codes, Perl 5.16 has 372 OP-Codes, see opnames.h. Each op represents a pp_*opname*() function. Note that some pp_ functions are just macros, several opcodes share the same function.
In Perl there are 12 different OP classes, that are related like the following class hierarchy diagram shows:

A typical small optree for `$a = $b + 42` would be:

```
$ perl-nonthreaded -MO=Concise -e '$a = $b + 42'
8  <@> leave[1 ref] vKP/REFC ->(end)
1     <0> enter ->2
2     <;> nextstate(main 1 -e:1) v:{ ->3
7     <2> sassign vKS/2 ->8
5        <2> add[t1] sK/2 ->6
-           <1> ex-rv2sv sK/1 ->4
3              <$> gvsv(*b) s ->4
4           <$> const(IV 42) s ->5
-        <1> ex-rv2sv sKRM*/1 ->7
6           <$> gvsv(*a) s ->7
```

```
$ perl-nonthreaded -MO=Concise,-exec -e
1  <0> enter
2  <;> nextstate(main 1 -e:1) v:{
3  <$> gvsv(*b) s
4  <$> const(IV 42) s
5  <2> add[t1] sK/2
6  <$> gvsv(*a) s
7  <2> sassign vKS/2
8  <@> leave[1 ref] vKP/REFC
```

(Note: ex-ops are Nullified)

We have two BINOPs, SASSIGN and ADD as <2> and three SVOPs, GVSV and CONST as <$>. *Note that for a threaded perl the GVSV OPs would have been PADOPs.* A SVOP pushes a SV onto the stack. A BINOP takes two args from the stack, and pushes a result.

B::Concise Types:

```
argnum:            opclass:         parsed op_flags:                             static opcode.
S scalar           0 baseop         v Want void                                  m needs stack
L list             1 unop           s Want scalar (single value)                 f fold constar
A array value      2 binop          l Want list of any length                    s always produ
H hash value       | logop          K Kids                                       t needs target
C code value       @ listop         P Parens, or block needs explicit scope entry T ... which ma
F file value       / pmop           R REF                                        i always produ
R scalar reference $ svop_or_padop  M MOD. Will modify (lvalue)                  I has correspo
                   # padop          S Stacked. Some arg is arriving on the stack d danger, unkr
                   " pvop_or_svop   * Special. Do something weird for this op    u defaults to
                   { loop
                   ; cop
                   % baseop_or_unop
                   - filestatop
                   } loopexop
```

For syntax trees and OP codes also see http://www.perlfoundation.org/perl5/index.cgi?optree_guts *and* http://books.simon-cozens.org/index.php/Perl_5_Internals.

Stacks

During compilation and runtime Perl use various stacks to manage itself and the program running. Several data stacks (variable scope and subroutine arguments), and also code context stacks (block context).

Scope

The first three data stacks implement **scopes**, including variables and values which are restored (or actions to be performed) when the scope is left.

The **`scopestack`** pushes the `savestack_ix` when `ENTER` is executed. On `LEAVE` the top `savestack_ix` entry is popped and all things saved on the `savestack` since this is restored. This means that a `ENTER/LEAVE` pairs represents dynamic nestable scopes.

The **`savestack`** contains records of things saved in order to be restored when the scopes are left. Each record consist of 2-4 ANY elements. The first one is a type code, which is used to decide how long the record is and how to interpret the other elements. (In the figure the type codes are marked pinkish color.) The restoring involves updating memory locations of various types as well as more general callbacks (destructors).

The **`tmps_stack`** implement mortal SVs. Each time a new mortal is made, then `tmps_ix` is incremented and the corresponding entry in `tmps_stack` made to point to it. When `SAVETMPS` is executed, then the old `tmps_floor` value is saved on the `savestack` and then `tmps_floor` is set equal to `tmps_ix`. When `FREETMPS` is executed, then all SVs pointed to by the pointers between `tmps_floor` and `tmps_ix` will have their REFCNT decremented. How many this will be depend on how many scopes has been left. Note that the `tmps_floor` and `tmps_ix` values is the index of the last SV* pushed. They both start out as -1 when the stack is empty.

The @_ stack

The next two stacks handle the arguments passed to subroutines, also the return values.

The first one is simply denoted as **the stack** and is really an AV. The variable **`curstack`** points to this AV. To speed up access Perl also maintain direct pointers to the start (`stack_base`) and the end (`stack_max`) of the allocated ARRAY of this AV. This AV is so special that it is marked as not REAL and the FILL field is not updated. Instead we use a dedicated pointed called `stack_sp`, the stack pointer. The stack is used to pass arguments to PP operations and subroutines and is also the place where the result of these operations as well as subroutine return values are placed.

The **`markstack`** is used to indicate the extent of the stack to be passed as @_ to Perl subroutines. When a subroutine is to be called, then first the start of the arguments are marked by pushing the `stack_sp` offset onto `markstack`, then the arguments themselves are calculated and pushed on the stack. Then the `@_` array is set up with pointers the SV* on the stack between the `MARK` and `stack_sp` and the subroutine starts running. For XSUB routines, the creation of `@_` is suppressed, and the routine will use the `MARK` directly to find it's arguments.

Context

The **`cxstack`** for *context stack* contains `cx` records that describe the current block context. Each time a subroutine, an eval, a loop, a format block or given/when block is entered, then a new PERL_CONTEXT cx record is pushed on the `cxstack`. When the context block finished at any LEAVE* op, then the top record is pop'ed and the corresponding values restored.

A cxstack record, the cx, is either a block context or subst context. A block context has a common header of size 6 and shares then structs for sub, format, eval, loop or given/when contexts also of size 6. The subst context is of size 12.

sub

The context setup for a Perl or XS subroutine does at **entersub**:

```
ENTER;
PUSHBLOCK(cx, CXt_SUB, SP);
PUSHSUB(cx);
cx->blk_sub.retop = PL_op->op_next;
CvDEPTH(cv)++;
SAVECOMPPAD();
PAD_SET_CUR_NOSAVE(CvPADLIST(cv), CvDEPTH(cv));
/* push args */
/* call sub */
```

and at **leavesub**

```
/* pop return value(s) */
POPBLOCK(cx,newpm);
LEAVE;
cxstack_ix--;
POPSUB(cx,sv);          /* release CV and @_ ... */
PL_curpm = newpm;       /* ... and pop $1 et al */
LEAVESUB(sv);
return cx->blk_sub.retop;
```

The *ENTER/LEAVE* pair handles the scope- and savestack.

The *PUSHBLOCK/POPBLOCK* pair handles the cxstack header of the current context, the special `blk_sub` values are handled in the subsequent SUB calls.
PUSHBLOCK arguments are the type and stack, the `POPBLOCK` return value `newpm` is the `cx->blk_oldpm`, which was `PL_curpm` at entry. `PUSHBLOCK` increments `cxstack_ix`, `POPBLOCK` does decrement it.

The *PUSHSUB/POPSUB* pair handles the `cx->blk_sub` record from the very same `cxstack`, the `POPSUB` return value `sv` is the `blk_sub.cv` which was the `cv` from `PUSHSUB`. `POPSUB` also releases `@_`, the `blk_sub.argarray`.

eval

An eval call is similar to a sub call. The **evaltry** and **eval** op for `eval{}` and `eval ""` just pack the op sequence into a simple try/catch switch between `JMPENV_PUSH` and `JMPENV_POP` calls.

The **struct jmpenv** packages the state required to perform a proper non-local jump, **top_env** being the initial JMPENV record. In case of abnormal exceptions (i.e. die) a `JMPENV_JUMP` must be done, a non-local jump out to the previous JMPENV level with a proper *setjmp* record.

<gisle@aas.no>
<rurban@x-ray.at>
$Date: 2012-04-04 01:01:53 rurban $