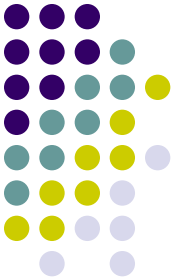
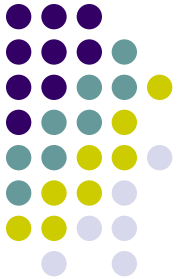
Посебни елементи физичке архитектуре и њихово искоришћење из Цеа

Груписање процесора по намени



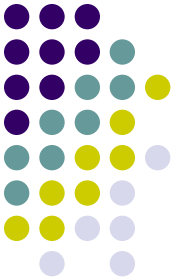
- Процесори опште намене

- Наменски процесори (Процесори посебне намене)
  - **ДСП-ови**
  - Микроконтролери
  - Графички процесори...



```
float aryA[N];
float aryB[N];
float aryC[N];

void conv() {
  int i;
  for (i = 0; i < N; ++i) {
    aryC[i] = aryA[i] * aryB[i];
  }
}
```

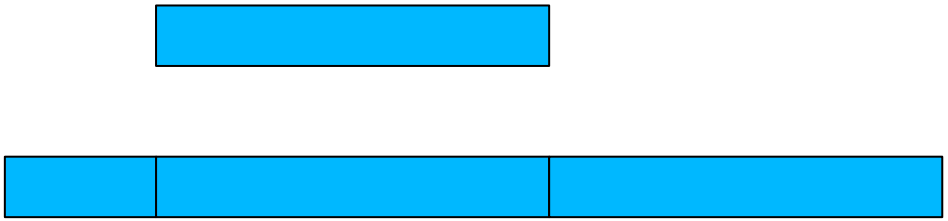
Аритметика у непокретном зарезу



```
1.000 (-1)   int a = 0x8; //1000    _Fract a = -1.0r;
0.011 (3/8)  int b = 0x3; //0011    _Fract b = 0.375r;

11.101000    int c = fp_mul(a, b); _Fract c = a * b;
     << 1
1.101000
```

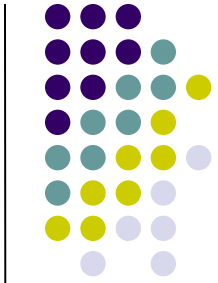
```
_Fract
long _Fract
_Accum
long _Accum

0.25r, 0.5lr, 5.6k, 50.7lk, 1.5r
```

Акумулатори



$$0.5 + 0.75 - 0.3 - 0.8 - 0.6 - 0.4 - 0.25 + 0.5 = -0.6$$

$$0.5 + 0.75 = 1.25$$
$$0.5 + 0.75 - 0.3 = 0.95$$
$$0.5 + 0.75 - 0.3 - 0.8 = 0.15$$
$$0.5 + 0.75 - 0.3 - 0.8 - 0.6 = -0.45$$
$$0.5 + 0.75 - 0.3 - 0.8 - 0.6 - 0.4 = -0.85$$
$$0.5 + 0.75 - 0.3 - 0.8 - 0.6 - 0.4 - 0.25 = -1.1$$
$$0.5 + 0.75 - 0.3 - 0.8 - 0.6 - 0.4 - 0.25 + 0.5 = -0.6$$

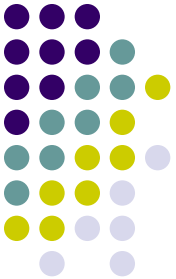


```
float aryA[N];
float aryB[N];
float aryC[N];

void conv() {
  int i;
  for (i = 0; i < N; ++i) {
    aryC[i] = aryA[i] * aryB[i];
  }
}
```

```
_Fract aryA[N];
_Fract aryB[N];
_Fract aryC[N];

void conv() {
  int i;
  for (i = 0; i < N; ++i) {
    aryC[i] = aryA[i] * aryB[i];
  }
}
```

```
_conv:
  a1 = 0
start:
  a1 > 30
  if (T) jmp end:
    i0 = _aryA + a1
    x0 = mem[i0]
    i0 = _aryB + a1
    y0 = mem[i0]
    a0 = x0 * y0
    i0 = _aryC + a1
    mem[i0] = a0
    a1 = a1 + 1
    jmp start
end:
    i7 = mem[i6]
    jmp i7
```

Адресни генератор



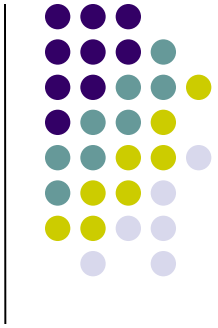
```
...ary[0];
...ary[2];
...ary[1];
...ary[2];
...ary[3];
```

```
p = ary;
...*p; p+=2
...*p--;
...*p++;
...*p++;
...*p;
```

```
struct s
{
  int a;
  int b;
  int c;
  int d;
};
```

```
struct s* ps;

...ps->d;
...ps->a;
...ps->c;
...ps->b;
```

```
struct s
{
  int d;
  int a;
  int c;
  int b;
};
```

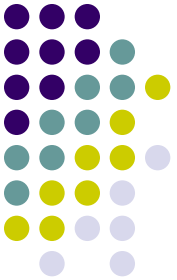


```
_Fract aryA[N];
_Fract aryB[N];
_Fract aryC[N];

void conv() {
  int i;
  for (i = 0; i < N; ++i) {
    aryC[i] = aryA[i] * aryB[i];
  }
}
```

```
void conv() {
  int i;
  _Fract* pA = &aryA[0];
  _Fract* pB = &aryB[0];
  _Fract* pC = &aryC[0];
  for (i = 0; i < N; ++i) {
    *pC++ = *pA++ * *pB++;
  }
}
```

```
_conv:
  a1 = 0
start:
  a1 > 30
  if (T) jmp end:
    i0 = _aryA + a1
    x0 = mem[i0]
    i0 = _aryB + a1
    y0 = mem[i0]
    a0 = x0 * y0
    i0 = _aryC + a1
    mem[i0] = a0
    a1 = a1 + 1
    jmp start
end:
    i7 = mem[i6]
    jmp i7
```

```
_conv:
  a1 = 0
start:
  a1 > 30
  if (T) jmp end:
    x0 = mem[i0]
    i0 = i0 + 1
    y0 = mem[i4]
    i4 = i4 + 1
    a0 = x0 * y0
    mem[i1] = a0
    i1 = i1 + 1
    a1 = a1 + 1
    jmp start
end:
    i7 = mem[i6]
    jmp i7
```



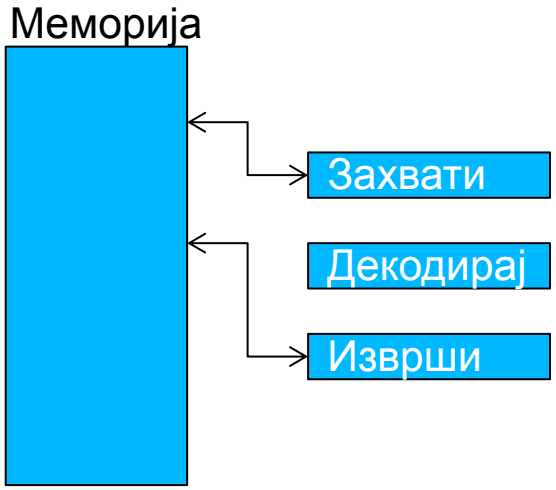
```
_Fract aryA[N];
_Fract aryB[N];
_Fract aryC[N];

void conv() {
  int i;
  for (i = 0; i < N; ++i) {
    aryC[i] = aryA[i] * aryB[i];
  }
}
```

```
void conv() {
  int i;
  _Fract* pA = &aryA[0];
  _Fract* pB = &aryB[0];
  _Fract* pC = &aryC[0];
  for (i = 0; i < N; ++i) {
    *pC++ = *pA++ * *pB++;
  }
}
```

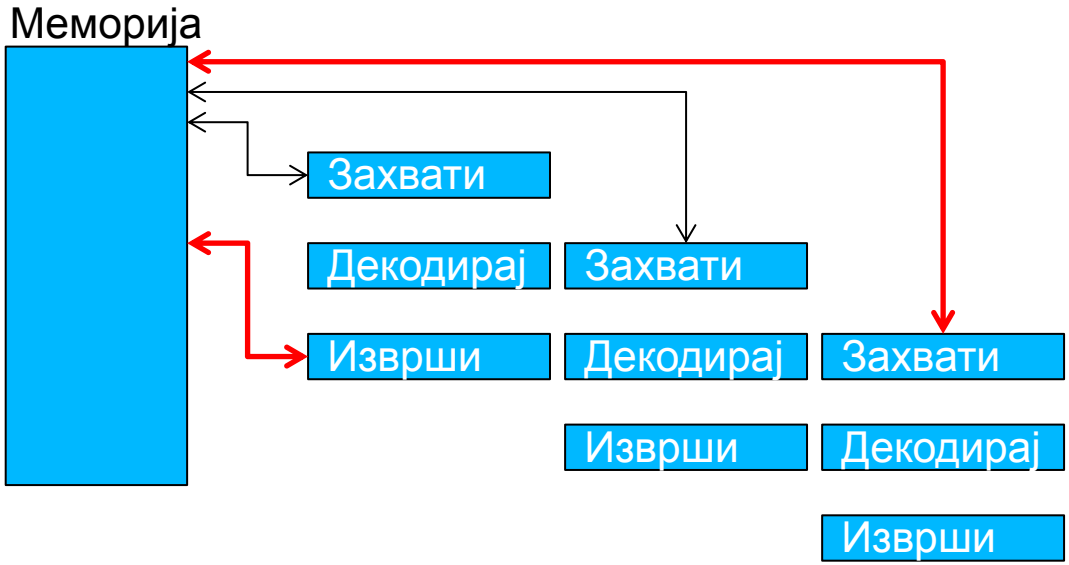
```
_conv:
  a1 = 0
start:
  a1 > 30
  if (T) jmp end:
    x0 = mem[i0]
    i0 = i0 + 1
    y0 = mem[i4]
    i4 = i4 + 1
    a0 = x0 * y0
    mem[i1] = a0
    i1 = i1 + 1
    a1 = a1 + 1
    jmp start
end:
    i7 = mem[i6]
    jmp i7
```

```
_conv:
  a1 = 0
start:
  a1 > 30
  if (T) jmp end:
    x0 = mem[i0]; i0 += 1
    y0 = mem[i4]; i4 += 1
    a0 = x0 * y0
    mem[i1] = a0; i1 += 1
    a1 = a1 + 1
    jmp start
end:
    i7 = mem[i6]
    jmp i7
```

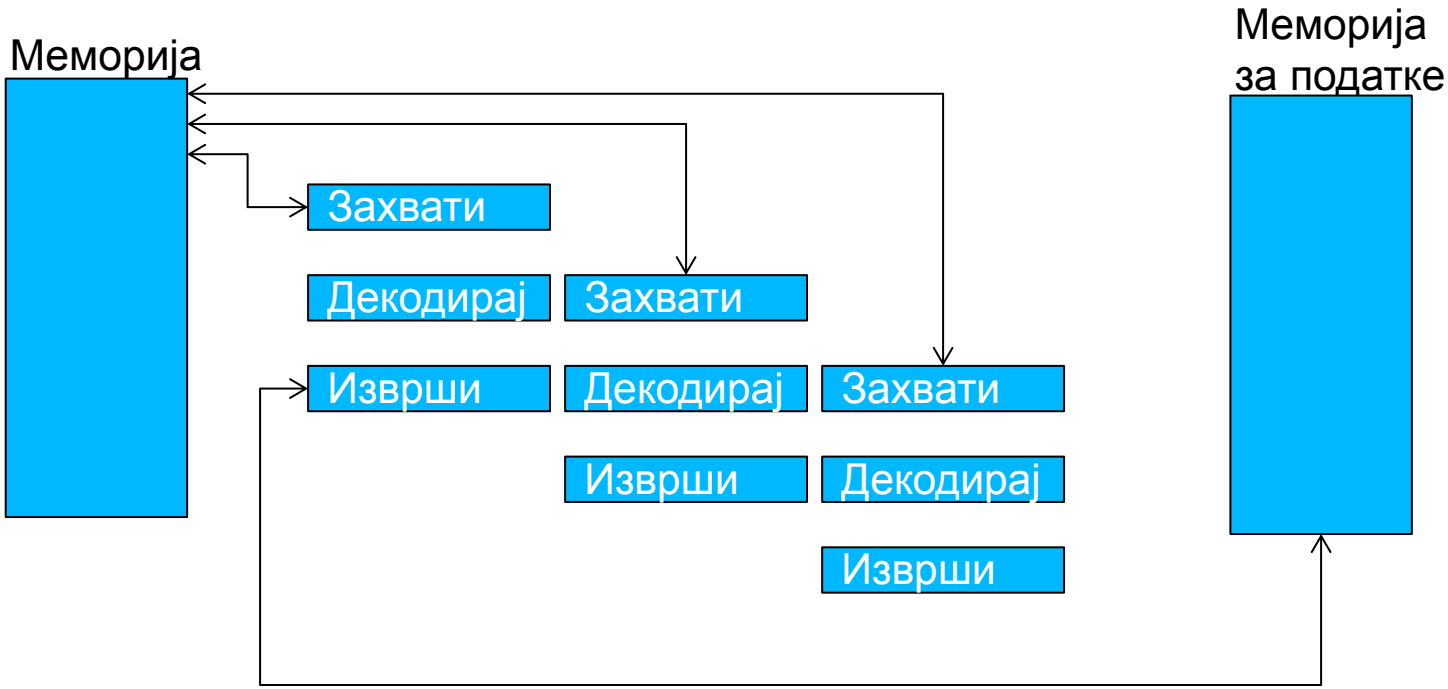
Харвард архитектура



Харвард архитектура



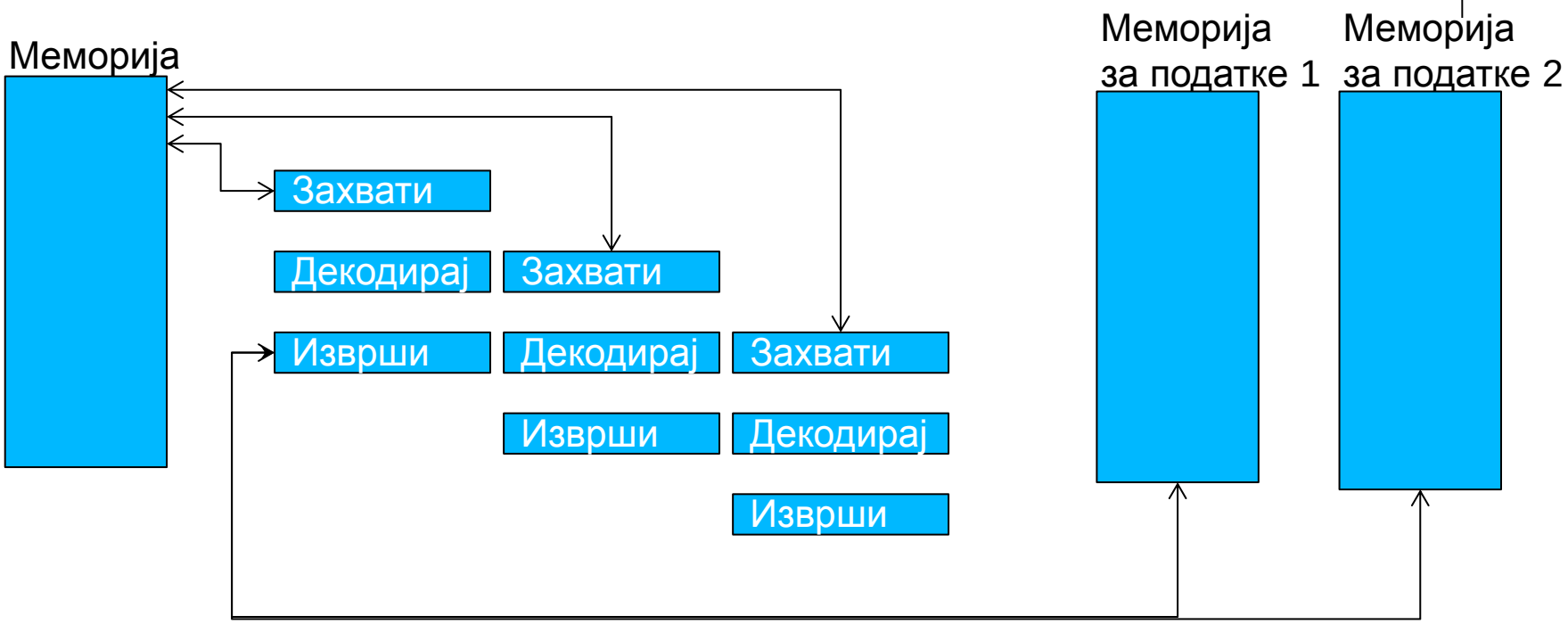
Харвард архитектура



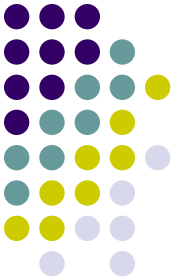

```
c = a * b
```

Колико приступа меморији?

Харвард архитектура



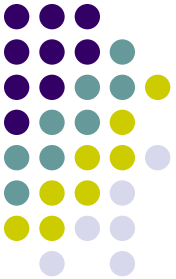

```
__memA int ary1[100];
__memB int ary2[100];
```



```
_Fract aryA[N];
_Fract aryB[N];
_Fract aryC[N];

void conv() {
  int i;
  _Fract* pA = &aryA[0];
  _Fract* pB = &aryB[0];
  _Fract* pC = &aryC[0];
  for (i = 0; i < N; ++i) {
    *pC++ = *pA++ * *pB++;
  }
}
```

```
__memX _Fract aryA[N];
__memY _Fract aryB[N];
__memX _Fract aryC[N];

void conv() {
  int i;
  for (i = 0; i < N; ++i) {
    aryC[i] = aryA[i] * aryB[i];
  }
}
```

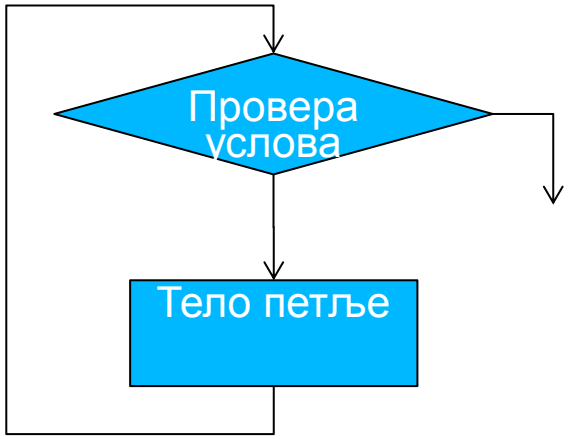
```
__memX _Fract aryA[N];
__memY _Fract aryB[N];
__memX _Fract aryC[N];

void conv() {
  int i;
  __memX _Fract* pA = &aryA[0];
  __memY _Fract* pB = &aryB[0];
  __memX _Fract* pC = &aryC[0];
  for (i = 0; i < N; ++i) {
    *pC++ = *pA++ * *pB++;
  }
}
```

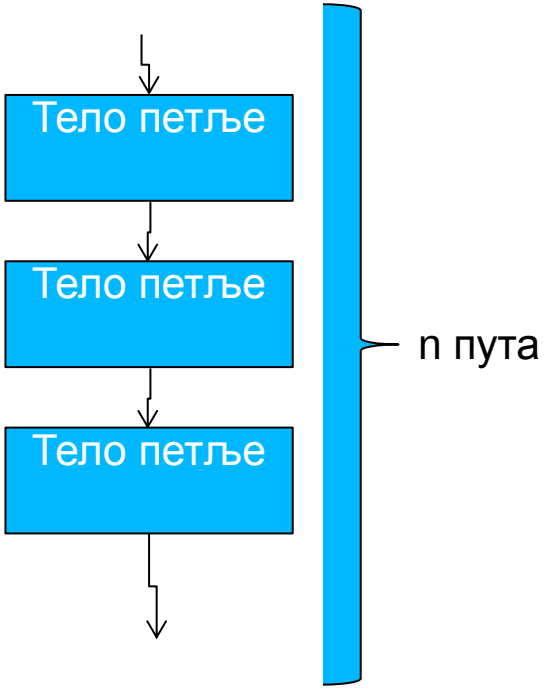


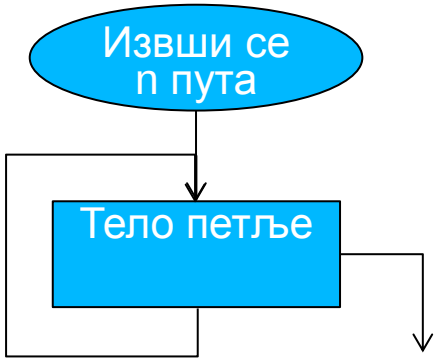
```
_conv:
  a1 = 0
start:
  a1 > 30
  if (T) jmp end:
    x0 = mem[i0]; i0 += 1
    y0 = mem[i4]; i4 += 1
    a0 = x0 * y0
    mem[i1] = a0; i1 += 1
    a1 = a1 + 1
    jmp start
end:
    i7 = mem[i6]
    jmp i7
```

```
_conv:
  a1 = 0
start:
  a1 > 30
  if (T) jmp end:
    x0 = xmem[i0]; i0 += 1; y0 = ymem[i4]; i4 += 1
    a0 = x0 * y0
    xmem[i1] = a0; i1 += 1
    a1 = a1 + 1
    jmp start
end:
    i7 = mem[i6]
    jmp i7
```

Хардверски подржане петље

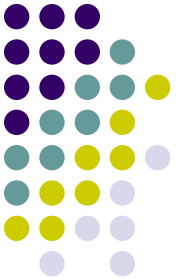




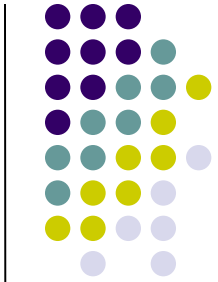


- Петље код којих је број итерација познат већ током превођења
- Петље код којих је број итерација познат пре него што петља почне

Хардверски подржане петље

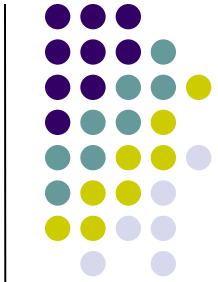


```
for (i = 0; i < NUMBER_OF_ITERATIONS; i++)
for (i = NUMBER_OF_ITERATIONS; i > 0; i--)
for (i = 0; i++ < NUMBER_OF_ITERATIONS; )
for (i = NUMBER_OF_ITERATIONS; i-- > 0; )
for (i = 0; i < NUMBER_OF_ITERATIONS; ++i)
for (i = NUMBER_OF_ITERATIONS;i>0; --i)
for (i = 0; ++i < NUMBER_OF_ITERATIONS + 1; )
for (i = NUMBER_OF_ITERATIONS + 1; --i > 0; )
```



```
__memX _Fract aryA[N];
__memY _Fract aryB[N];
__memX _Fract aryC[N];

void conv() {
  int i;
  for (i = 0; i < N; ++i) {
    aryC[i] = aryA[i] * aryB[i];
  }
}
```

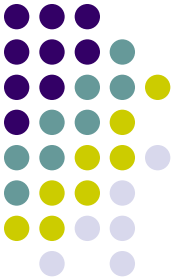
```
__memX _Fract aryA[N];
__memY _Fract aryB[N];
__memX _Fract aryC[N];

void conv() {
  int i;
  __memX _Fract* pA = &aryA[0];
  __memY _Fract* pB = &aryB[0];
  __memX _Fract* pC = &aryC[0];
  for (i = 0; i < N; ++i) {
    *pC++ = *pA++ * *pB++;
  }
}
```



```
_conv:
  a1 = 0
start:
  a1 > 30
  if (T) jmp end:
    x0 = xmem[i0]; i0 += 1; y0 = ymem[i4]; i4 += 1
    a0 = x0 * y0
    xmem[i1] = a0; i1 += 1
    a1 = a1 + 1
    jmp start
end:
    i7 = mem[i6]
    jmp i7
```

```
_conv:
  hw_loop(31), end
    x0 = xmem[i0]; i0 += 1; y0 = ymem[i4]; i4 += 1
    a0 = x0 * y0
    xmem[i1] = a0; i1 += 1
end:
    i7 = mem[i6]
    jmp i7
```

Хардверски стек позива функција

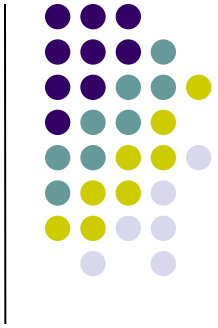


```
push pc
jmp addr
```

```
call addr
```

```
pop reg
jmp reg
```

```
ret
```

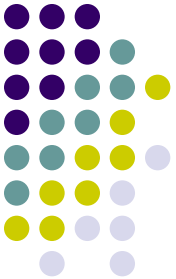


```
_conv:
  hw_loop(31), end
    x0 = xmem[i0]; i0 += 1; y0 = ymem[i4]; i4 += 1
    a0 = x0 * y0
    xmem[i1] = a0; i1 += 1
end:
    i7 = mem[i6]
    jmp i7
```

```
_conv:
  hw_loop(31), end
    x0 = xmem[i0]; i0 += 1; y0 = ymem[i4]; i4 += 1
    a0 = x0 * y0
    xmem[i1] = a0; i1 += 1
end:
    ret
```

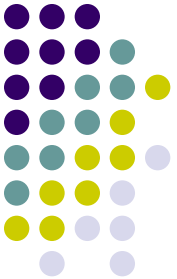
```
i6 += 1                        call conv
xmem[i6] = pc
jmp conv
```

Хардверски подржан кружни бафер



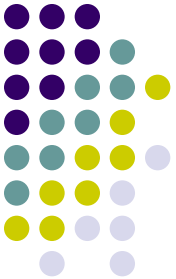
```
__attribute__(align(128))


p = ary;
for (...)
{
    ...*p...
    p = CIRC_INC(p, MOD128, 1);
}
```

Векторске операције



```
int8_t A[100];
int8_t B[100];
int8_t C[100];
for (i = 0; i < 100; i++)
{
    C[i] = A[i] + B[i];
}

int8_t __attribute__ ((vector_size(4))) A[25];
int8_t __attribute__ ((vector_size(4))) B[25];
int8_t __attribute__ ((vector_size(4))) C[25];
for (i = 0; i < 25; i++)
{
    C[i] = __builtin_add_qb(A[i], B[i]);
}

int8_t __attribute__ ((vector_size(4))) x = {1, 2, 3, 4};
```

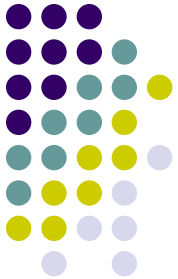
Две врсте окружења у којима се Це програми извршавају



Це стандард идентификује две категорије окружења:

- Подржавано (енгл. Hosted)
  - Претпоставља се постојање релативно раскошног ОС-а и имплементација свих библиотечких функција.
  - Функција main представља почетну тачку извршавања
- Неподржавано (енгл. Freestanding)
  - ОС може пружати само елементарне ствари, а од библиотека се очекује само: float.h, iso646.h, limits.h, stdarg.h, stdbool.h, stddef.h.
  - Функција main нема никакву посебност. Механизам почињана извршавања програма може бити произвољан.
  - Нема (тј. не мора бити) комплексног типа.

Зашто програми не раде добро?



Зашто програми не раде добро?

Једна анализа у домену уграђених система показује:

- 43% проблема настаје због спецификације
- 21% услед промене спецификације након завршетка развоја
- 15% током коришћења и одржавања
- **15% током развоја и имплементације**
- 6% током инсталације и испоруке

MISRA C
(обавезно прочитати поглавља [1,3])

- Rule 1.2 (required): No reliance shall be placed on undefined or unspecified behavior.
- Rule 2.4 (advisory): Sections of code should not be “commented out”.
- Rule 3.1 (required): All usage of implementation-defined behavior shall be documented.
- Rule 5.2 (required): Identifiers in an inner scope shall not use the same name as an identifier in an outer scope, and therefore hide that identifier.
- Rule 6.1 (required): The plain char type shall be used only for the storage and use of character values.
- Rule 7.1 (required): Octal constants (other than zero) and octal escape sequences shall not be used.
- Rule 8.5 (required) There shall be no definitions of objects or functions in a headerfile.
- Rule 8.6 (required): Functions shall be declared at file scope.
- Rule 16.2 (required): Functions shall not call themselves, either directly or indirectly.