Streaming I/O (Memory Mapping)

System Message: ERROR/3 (D:\onboarding-resources\sample-onboarding-resources\linux-master\Documentation\userspace-api\media\v4l\[linux-master][Documentation][userspace-api][media][v4l]mmap.rst, line 2)

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```
.. c:namespace:: V4L
```

Input and output devices support this I/O method when the `V4L2_CAP_STREAMING` flag in the `capabilities` field of struct :c:type:`v4l2_capability` returned by the :ref:`VIDIOC_QUERYCAP` ioctl is set. There are two streaming methods, to determine if the memory mapping flavor is supported applications must call the :ref:`VIDIOC_REQBUFS` ioctl with the memory type set to `V4L2_MEMORY_MMAP`.

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Streaming is an I/O method where only pointers to buffers are exchanged between application and driver, the data itself is not copied. Memory mapping is primarily intended to map buffers in device memory into the application's address space. Device memory can be for example the video memory on a graphics card with a video capture add-on. However, being the most efficient I/O method available for a long time, many other drivers support streaming as well, allocating buffers in DMA-able main memory.

A driver can support many sets of buffers. Each set is identified by a unique buffer type value. The sets are independent and each set can hold a different type of data. To access different sets at the same time different file descriptors must be used. [1]

To allocate device buffers applications call the :ref:`VIDIOC_REQBUFS` ioctl with the desired number of buffers and buffer type, for example `V4L2_BUF_TYPE_VIDEO_CAPTURE`. This ioctl can also be used to change the number of buffers or to free the allocated memory, provided none of the buffers are still mapped.

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Before applications can access the buffers they must map them into their address space with the :c:func:`mmap()` function. The location of the buffers in device memory can be determined with the :ref:`VIDIOC_QUERYBUF` ioctl. In the single-planar API case, the `m.offset` and `length` returned in a struct :c:type:`v4l2_buffer` are passed as sixth and second parameter to the :c:func:`mmap()` function. When using the multi-planar API, struct :c:type:`v4l2_buffer` contains an array of struct :c:type:`v4l2_plane` structures, each containing its own `m.offset` and `length`. When using the multi-planar API, every plane of every buffer has to be mapped separately, so the number of calls to :c:func:`mmap()` should be equal to number of buffers times number of planes in each buffer. The offset and length values must not be modified. Remember, the buffers are allocated in physical memory, as opposed to virtual memory, which can be swapped out to disk. Applications should free the buffers as soon as possible with the :c:func:`munmap()` function.

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System Message: ERROR/3 (D:\onboarding-resources\sample-onboarding-resources\linux-master\Documentation\userspace-api\media\v4l\[linux-master][Documentation][userspace-api][media][v4l]mmap.rst, line 38); *backlink*

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Example: Mapping buffers in the single-planar API

```
struct v4l2_requestbuffers reqbuf;
struct {
    void *start;
    size_t length;
} *buffers;
unsigned int i;

memset(&reqbuf, 0, sizeof(reqbuf));
reqbuf.type = V4L2_BUF_TYPE_VIDEO_CAPTURE;
reqbuf.memory = V4L2_MEMORY_MMAP;
reqbuf.count = 20;

if (-1 == ioctl (fd, VIDIOC_REQBUFS, &reqbuf)) {
    if (errno == EINVAL)
        printf("Video capturing or mmap-streaming is not supported\\n");
    else
        perror("VIDIOC_REQBUFS");

    exit(EXIT_FAILURE);
}

/* We want at least five buffers. */
```

```
if (reqbuf.count < 5) {
    /* You may need to free the buffers here. */
    printf("Not enough buffer memory\\n");
    exit(EXIT_FAILURE);
}

buffers = calloc(reqbuf.count, sizeof(*buffers));
assert(buffers != NULL);

for (i = 0; i < reqbuf.count; i++) {
    struct v4l2_buffer buffer;

    memset(&buffer, 0, sizeof(buffer));
    buffer.type = reqbuf.type;
    buffer.memory = V4L2_MEMORY_MMAP;
    buffer.index = i;

    if (-1 == ioctl (fd, VIDIOC_QUERYBUF, &buffer)) {
        perror("VIDIOC_QUERYBUF");
        exit(EXIT_FAILURE);
    }

    buffers[i].length = buffer.length; /* remember for munmap() */

    buffers[i].start = mmap(NULL, buffer.length,
                PROT_READ | PROT_WRITE, /* recommended */
                MAP_SHARED,             /* recommended */
                fd, buffer.m.offset);

    if (MAP_FAILED == buffers[i].start) {
        /* If you do not exit here you should unmap() and free()
           the buffers mapped so far. */
        perror("mmap");
        exit(EXIT_FAILURE);
    }
}

/* Cleanup. */

for (i = 0; i < reqbuf.count; i++)
    munmap(buffers[i].start, buffers[i].length);
```

Example: Mapping buffers in the multi-planar API

```
struct v4l2_requestbuffers reqbuf;
/* Our current format uses 3 planes per buffer */
#define FMT_NUM_PLANES = 3

struct {
    void *start[FMT_NUM_PLANES];
    size_t length[FMT_NUM_PLANES];
} *buffers;
unsigned int i, j;

memset(&reqbuf, 0, sizeof(reqbuf));
reqbuf.type = V4L2_BUF_TYPE_VIDEO_CAPTURE_MPLANE;
reqbuf.memory = V4L2_MEMORY_MMAP;
reqbuf.count = 20;

if (ioctl(fd, VIDIOC_REQBUFS, &reqbuf) < 0) {
    if (errno == EINVAL)
        printf("Video capturing or mmap-streaming is not supported\\n");
    else
        perror("VIDIOC_REQBUFS");

    exit(EXIT_FAILURE);
}

/* We want at least five buffers. */

if (reqbuf.count < 5) {
    /* You may need to free the buffers here. */
    printf("Not enough buffer memory\\n");
    exit(EXIT_FAILURE);
}

buffers = calloc(reqbuf.count, sizeof(*buffers));
assert(buffers != NULL);
```

```
for (i = 0; i < reqbuf.count; i++) {
    struct v4l2_buffer buffer;
    struct v4l2_plane planes[FMT_NUM_PLANES];

    memset(&buffer, 0, sizeof(buffer));
    buffer.type = reqbuf.type;
    buffer.memory = V4L2_MEMORY_MMAP;
    buffer.index = i;
    /* length in struct v4l2_buffer in multi-planar API stores the size
     * of planes array. */
    buffer.length = FMT_NUM_PLANES;
    buffer.m.planes = planes;

    if (ioctl(fd, VIDIOC_QUERYBUF, &buffer) < 0) {
        perror("VIDIOC_QUERYBUF");
        exit(EXIT_FAILURE);
    }

    /* Every plane has to be mapped separately */
    for (j = 0; j < FMT_NUM_PLANES; j++) {
        buffers[i].length[j] = buffer.m.planes[j].length; /* remember for munmap() */

        buffers[i].start[j] = mmap(NULL, buffer.m.planes[j].length,
                 PROT_READ | PROT_WRITE, /* recommended */
                 MAP_SHARED,             /* recommended */
                 fd, buffer.m.planes[j].m.offset);

        if (MAP_FAILED == buffers[i].start[j]) {
            /* If you do not exit here you should unmap() and free()
               the buffers and planes mapped so far. */
            perror("mmap");
            exit(EXIT_FAILURE);
        }
    }
}

/* Cleanup. */

for (i = 0; i < reqbuf.count; i++)
    for (j = 0; j < FMT_NUM_PLANES; j++)
        munmap(buffers[i].start[j], buffers[i].length[j]);
```

Conceptually streaming drivers maintain two buffer queues, an incoming and an outgoing queue. They separate the synchronous capture or output operation locked to a video clock from the application which is subject to random disk or network delays and preemption by other processes, thereby reducing the probability of data loss. The queues are organized as FIFOs, buffers will be output in the order enqueued in the incoming FIFO, and were captured in the order dequeued from the outgoing FIFO.

The driver may require a minimum number of buffers enqueued at all times to function, apart of this no limit exists on the number of buffers applications can enqueue in advance, or dequeue and process. They can also enqueue in a different order than buffers have been dequeued, and the driver can *fill* enqueued *empty* buffers in any order. [2] The index number of a buffer (struct :c:type:`v4l2_buffer` `index`) plays no role here, it only identifies the buffer.

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Initially all mapped buffers are in dequeued state, inaccessible by the driver. For capturing applications it is customary to first enqueue all mapped buffers, then to start capturing and enter the read loop. Here the application waits until a filled buffer can be dequeued, and re-enqueues the buffer when the data is no longer needed. Output applications fill and enqueue buffers, when enough buffers are stacked up the output is started with :ref:`VIDIOC_STREAMON <VIDIOC_STREAMON>`. In the write loop, when the application runs out of free buffers, it must wait until an empty buffer can be dequeued and reused.

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To enqueue and dequeue a buffer applications use the :ref:`VIVIOC_QBUF <VIDIOC_QBUF>` and :ref:`VIDIOC_DQBUF <VIDIOC_QBUF>` ioctl. The status of a buffer being mapped, enqueued, full or empty can be determined at any time using the :ref:`VIDIOC_QUERYBUF` ioctl. Two methods exist to suspend execution of the application until one or more buffers can be dequeued. By default :ref:`VIDIOC_DQBUF <VIDIOC_QBUF>` blocks when no buffer is in the outgoing queue. When the

O_NONBLOCK flag was given to the :c:func:`open()` function, :ref:`VIDIOC_DQBUF <VIDIOC_QBUF>` returns immediately with an EAGAIN error code when no buffer is available. The :c:func:`select()` or :c:func:`poll()` functions are always available.

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To start and stop capturing or output applications call the :ref:`VIDIOC_STREAMON <VIDIOC_STREAMON>` and :ref:`VIDIOC_STREAMOFF <VIDIOC_STREAMON>` ioctl.

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Drivers implementing memory mapping I/O must support the :ref:`VIDIOC_REQBUFS <VIDIOC_REQBUFS>`, :ref:`VIDIOC_QUERYBUF <VIDIOC_QUERYBUF>`, :ref:`VIDIOC_QBUF <VIDIOC_QBUF>`, :ref:`VIDIOC_DQBUF <VIDIOC_QBUF>`, :ref:`VIDIOC_STREAMON <VIDIOC_STREAMON>` and :ref:`VIDIOC_STREAMOFF <VIDIOC_STREAMON>` ioctls, the :ref:`mmap() <func-mmap>`, :c:func:`munmap()`, :ref:`select() <func-select>` and :c:func:`poll()` function. [3]

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[capture example]

[1] One could use one file descriptor and set the buffer type field accordingly when calling :ref:`VIDIOC_QBUF` etc., but it makes the :c:func:`select()` function ambiguous. We also like the clean approach of one file descriptor per logical stream. Video overlay for example is also a logical stream, although the CPU is not needed for continuous operation.

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[2] Random enqueue order permits applications processing images out of order (such as video codecs) to return buffers earlier, reducing the probability of data loss. Random fill order allows drivers to reuse buffers on a LIFO-basis, taking advantage of caches holding scatter-gather lists and the like.

[3] At the driver level :c:func:`select()` and :c:func:`poll()` are the same, and :c:func:`select()` is too important to be optional. The rest should be evident.

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