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Alternate `atomic_ref` for Non-Lockfree Types

```
git clone git@github.com:dsunder/draft.git dsunder-draft
cd dsunder-draft
git checkout atomic_ref_alt
```

Motivation

Enable implementations of `atomic_ref` which do not require a global lock array while perserving current behavior as much as possible.

Proposed Wording

This font is used to provide guidance to the editors.

Make the following changes in [atomics.ref.generic].

```
namespace std {
  struct atomic_ref_assume_lock_free_t    {};
  struct atomic_ref_assume_no_user_lock_t {};
  struct atomic_ref_prefer_user_lock_t    {};

  inline constexpr atomic_ref_assume_lock_free_t  atomic_ref_assume_lock_free {};
  inline constexpr atomic_ref_prefer_user_lock_t  atomic_ref_prefer_user_lock {};
}
namespace std {

  template<class T, class LockT=unspecified> struct atomic_ref {
  private:
    T* ptr;       // exposition only
    Lock* ulock; // exposition only
  public:
    using Lock = LockT;
    using value_type = T;
    static constexpr bool is_always_lock_free = implementation-defined;
    static constexpr bool never_requires_user_lock = implementation-defined;
    static constexpr size_t required_lock_free_alignment = implementation-defined;

    static bool is_lock_free(const T &) noexcept;
    static bool requires_user_lock(const T &) noexcept;

    atomic_ref& operator=(const atomic_ref&) = delete;

    explicit atomic_ref(T&) noexcept;
    atomic_ref(T&, atomic_ref_assume_lock_free_t) noexcept;

    atomic_ref(T&, Lock&) noexcept;
    atomic_ref(T&, Lock&, atomic_ref_prefer_user_lock_t) noexcept;

    template<class Select> atomic_ref(T&, ranges::RandomAccessRange<Lock>,
     Select = unspecified) noexcept;
    template<class Select> atomic_ref(T&, ranges::RandomAccessRange<Lock>,
     atomic_ref_prefer_user_lock_t, Select = unspecified) noexcept;

    atomic_ref(const atomic_ref&) noexcept;

    T operator=(T) const noexcept;
    operator T() const noexcept;

    bool is_lock_free() const noexcept;
    void store(T, memory_order = memory_order_seq_cst) const noexcept;
    T load(memory_order = memory_order_seq_cst) const noexcept;
    T exchange(T, memory_order = memory_order_seq_cst) const noexcept;
    bool compare_exchange_weak(T&, T,
                               memory_order, memory_order) const noexcept;
    bool compare_exchange_strong(T&, T,
                                 memory_order, memory_order) const noexcept;
    bool compare_exchange_weak(T&, T,
                               memory_order = memory_order_seq_cst) const noexcept;
```

```
    bool compare_exchange_strong(T&, T,
                                 memory_order = memory_order_seq_cst) const noexcept;
  };
}
```

Make the following changes in [atomics.ref.operations].

`atomic_ref` instances referencing the same value of ptr and ulock are called *equivalent*. Concurrent access to the same value through equivalent `atomic_ref` instances does not create a data race. [*Note*: Concurrent access to the value directly, or through a non-equivalent `atomic_ref` instance, may introduce a data race. — *end note*]

`static constexpr bool is_always_lock_free;`

1 The static data member `is_always_lock_free` is `true` if the `atomic_ref` type's operations are always lock-free on objects aligned to `required_lock_free_alignment`, and `false` otherwise.

`static constexpr size_t required_lock_free_alignment;`

2 The alignment required for an object to be referenced lock-free by an atomic reference, which is at least `alignof(T)`.

3 [*Note*: Hardware could require an object referenced by an `atomic_ref` to have stricter alignment (??) than other objects of type `T`. Furthermore, whether operations on an `atomic_ref` are lock-free could depend on the alignment of the referenced object. For example, lock-free operations on `std::complex<double>` could be supported only if aligned to `2*alignof(double)`. — *end note*]

`static constexpr bool never_requires_user_lock;`

4 Is `true` if an implementation never requires the user to provide a lock for objects of type `T` and `false` otherwise.

`static is_lock_free(T& obj) noexcept;`

Returns: Returns `true` if atomic operations on the object referenced by `obj` can be lock-free or if the `Lock` type is equivalent to `atomic_ref_assume_lock_free_t`.

`static requires_user_lock(T& obj) noexcept;`

Returns: Returns `false` if the type `Lock` is equivalent to either `atomic_ref_assume_lock_free_t` or `atomic_ref_assume_no_user_lock_t`. Otherwise, returns `true` if `atomic_ref` requires the user to provide a valid reference to a `Lock` object or a non-empty `ranges::RandomAccessRange<Lock>` when constructing an `atomic_ref` from `obj`.

`explicit atomic_ref(T& obj) noexcept`*(see below)*`;`

5 *Mandates:* If type `Lock` is either equivalent to `atomic_ref_assume_lock_free_t` or `atomic_ref_assume_no_user_lock_t` then the implementation can possibly be lock-free or not require a user provided lock for some objects of type `T` respectively.

6 ~~*Requires:* The referenced object shall be aligned to `required_lock_free_alignment`~~. *Expects:* The type `Lock` either meets the *Cpp17BasicLockable* requirements, `Lock` is equivalent to `atomic_ref_assume_lock_free_t`, or `Lock` is equivalent to `atomic_ref_assume_no_user_lock_t`. Furthermore, `requires_user_lock(obj)` is `false`.

7 *Effects:* ~~Constructs an atomic reference that references the object.~~
Equivalent to:

```
ptr = &obj;
ulock = nullptr;
```

8 *Throws:* Nothing.

9 *Remarks:* Calls `terminate()` if `requires_user_lock(obj)` is `true`.

`atomic_ref(T& obj, atomic_ref_assume_lock_free_t);`

10 *Mandates:* If type `Lock` is either equivalent to `atomic_ref_assume_lock_free_t` or `atomic_ref_assume_no_user_lock_t` then the implementation can possibly be lock-free or not require a user provided lock for some objects of type `T` respectively.

11 *Expects:* The type `Lock` either meets the *Cpp17BasicLockable* requirements, `Lock` is equivalent to `atomic_ref_assume_lock_free_t`, or `Lock` is equivalent to `atomic_ref_assume_no_user_lock_t`. Furthermore, the object referenced `obj` is be aligned to `required_lock_free_alignment`.

12 *Effects:* Equivalent to:

```
ptr = &obj;
ulock = nullptr;
```

13 *Throws:* Nothing.

14 *Remarks:* Calls `terminate` if `is_lock_free(obj)` is `false`.

`atomic_ref(T& obj, Lock& lk);`

15 *Mandates:* If type `Lock` is either equivalent to `atomic_ref_assume_lock_free_t` or `atomic_ref_assume_no_user_lock_t` then the implementation can possibly be lock-free or not require a user provided lock for some objects of type `T` respectively.

16 *Expects:* The type `Lock` either meets the *Cpp17BasicLockable* requirements, `Lock` is equivalent to `atomic_ref_assume_lock_free_t`, or `Lock` is equivalent to `atomic_ref_assume_no_user_lock_t`. Furthermore, either `requires_user_lock(obj)` is false or all `atomic_ref` objects which concurrently reference the object referenced by `obj` are equivalent.

17 *Effects:* Equivalent to:

```
ptr = &obj;
ulock = requires_user_lock(obj) ? &lk : nullptr;
```

18 *Throws:* Nothing.

`atomic_ref(T& obj, Lock& lk, atomic_ref_prefer_user_lock_t);`

19 *Mandates:* If type `Lock` is either equivalent to `atomic_ref_assume_lock_free_t` or `atomic_ref_assume_no_user_lock_t` then the implementation can possibly be lock-free or not require a user provided lock for some objects of type `T` respectively.

20 *Expects:* The type `Lock` either meets the *Cpp17BasicLockable* requirements, `Lock` is equivalent to `atomic_ref_assume_lock_free_t`, or `Lock` is equivalent to `atomic_ref_assume_no_user_lock_t`. Furthermore, all `atomic_ref` objects which concurrently reference the object referenced by `obj` are equivalent.

21 *Effects:* Equivalent to:

```
ptr = &obj;
ulock = is_lock_free(obj) ? nullptr : &lk;
```

22 *Throws:* Nothing.

```
template <class Select>
atomic_ref(T& obj, ranges::RandomAccessRange<Lock> lks,
  Select sel = unspecified );
```

23 *Mandates:* If type `Lock` is either equivalent to `atomic_ref_assume_lock_free_t` or `atomic_ref_assume_no_user_lock_t` then the implementation can possibly be lock-free or not require a user provided lock for some objects of type `T` respectively. Furthermore, `INVOKE(sel(const T&, ranges::RandomAccessRange<Lock>))` returns a reference to an object of type `Lock`.

24 *Expects:* The type `Lock` either meets the *Cpp17BasicLockable* requirements, `Lock` is equivalent to `atomic_ref_assume_lock_free_t`, or `Lock` is equivalent to `atomic_ref_assume_no_user_lock_t`. Also, the range `lks` is non-empty and `INVOKE(sel(obj, lks))` returns a reference to a `Lock` object in the range of `lks`. Furthermore, either `require` is `false` or for all `atomic_ref` objects which concurrently reference the object referenced by `obj` are equivalent.

25 *Effects:* Equivalent to:

```
ptr = &obj;
ulock = requires_user_lock(obj) ?
  std::addressof(INVOKE(sel(obj, lks))) : nullptr;
```

26 *Throws:* Nothing.

27 *Remarks:* Calls `terminate` if the range `lks` is empty. `requires_user_lock(obj)` is `true`.

```
template <class Select>
atomic_ref(T& obj, ranges::RandomAccessRange<Lock> lks,
  atomic_ref_prefer_user_lock_t, Sel sel = unspecified );
```

28 *Mandates:* If type `Lock` is either equivalent to `atomic_ref_assume_lock_free_t` or `atomic_ref_assume_no_user_lock_t` then the implementation can possibly be lock-free or not require a user provided lock for some objects of type `T` respectively. Furthermore, `INVOKE(sel(const T&, ranges::RandomAccessRange<Lock>))` returns a reference to an object of type `Lock`.

29 *Expects:* The type `Lock` either meets the *Cpp17BasicLockable* requirements, `Lock` is equivalent to `atomic_ref_assume_lock_free_t`, or `Lock` is equivalent to `atomic_ref_assume_no_user_lock_t`. Also, the range `lks` is non-empty and `INVOKE(sel(obj, lks))` returns a reference to a `Lock` object in the range of `lks`. Furthermore, all `atomic_ref` objects which concurrently reference the object referenced by `obj` are equivalent.

30 *Effects:* Equivalent to:

```
ptr = &obj;
ulock = is_lock_free(obj) ?
  nullptr: std::addressof(INVOKE(sel(obj, lks)));
```

31 *Throws:* Nothing.

32 *Remarks:* Calls `terminate` if the range `lks` is empty and `is_lock_free(obj)` is `false`.

```
atomic_ref(const atomic_ref& ref) noexcept;
```

33 *Effects:* ~~Constructs an atomic reference that references the object referenced by `ref`.~~ Equivalent to:

```
ptr = ref.obj;
ulock = ref.ulock;
```

```
void store(T desired, memory_order order = memory_order_seq_cst) const noexcept;
```

34 ~~*Requires:*~~ *Expects:* The `order` argument shall not be `memory_order_consume`, `memory_order_acquire`, nor `memory_order_acq_rel`.

35 ~~Atomically replaces the value referenced by `*ptr` with the value of `desired`~~. *Effects:* If `ulock` is equivalent to `nullptr` then the operation is equivalent to atomically performing the following:

```
memcpy(ptr, &desired, sizeof(T));
```

Otherwise, equivalent to:

```
ulock->lock();
memcpy(ptr, &desired, sizeof(T));
ulock->unlock();
```

Memory is affected according to the value of `order`.

```
T load(memory_order order = memory_order_seq_cst) const noexcept;
```

36 ~~*Requires:*~~ *Expects:* The `order` argument shall not be `memory_order_release` nor `memory_order_acq_rel`.

37 *Effects:* If `ulock` is equivalent to `nullptr` then the operation is equivalent to atomically performing the following:

```
alignas(T) char result[sizeof(T)];
memcpy(result, ptr, sizeof(T));
return *reinterpret_cast<T*>(result);
```

Otherwise, equivalent to:

```
alignas(T) char result[sizeof(T)];
ulock->lock();
```

```
memcpy(result, ptr, sizeof(T));
ulock->unlock();
return *reinterpret_cast<T*>(result);
```

Memory is affected according to the value of `order`.

38 ~~*Returns:* Atomically returns the value referenced by `*ptr`.~~

```
T exchange(T desired, memory_order order = memory_order_seq_cst) const noexcept;
```

39 ~~Atomically replaces the value referenced by `*ptr` with `desired`.~~ *Effects:* If `ulock` is equivalent to `nullptr` then the operation is equivalent to atomically performing the following:

```
alignas(T) char result[sizeof(T)];
memcpy(result, ptr, sizeof(T));
memcpy(ptr, &desired, sizeof(T));
return *reinterpret_cast<T*>(result);
```

Otherwise, equivalent to:

```
alignas(T) char result[sizeof(T)];
ulock->lock();
memcpy(result, ptr, sizeof(T));
memcpy(ptr, &desired, sizeof(T));
ulock->unlock();
return *reinterpret_cast<T*>(result);
```

Memory is affected according to the value of `order`. This operation is an atomic read-modify-write operation (**??**).

40 *Returns:* Atomically returns the value referenced by `*ptr` immediately before the effects.

```
bool compare_exchange_weak(T& expected, T desired,
                           memory_order success, memory_order failure) const noexcept;

bool compare_exchange_strong(T& expected, T desired,
                             memory_order success, memory_order failure) const noexcept;

bool compare_exchange_weak(T& expected, T desired,
                           memory_order order = memory_order_seq_cst) const noexcept;

bool compare_exchange_strong(T& expected, T desired,
                             memory_order order = memory_order_seq_cst) const noexcept;
```

41 ~~*Requires:*~~ *Expects:* The `failure` argument shall not be `memory_order_release` nor `memory_order_acq_rel`.

42 *Effects:* When only one `memory_order` argument is supplied, the value of `success` is `order`, and the value of `failure` is `order` except that a value of `memory_order_acq_rel` shall be replaced by the value `memory_order_acquire` and a value of `memory_order_release` shall be replaced by the value `memory_order_relaxed`.

If `ulock` is equivalent to `nullptr` then the operation is equivalent to atomically performing the following:

```
alignas(T) char old[sizeof(T)];
memcpy(old, ptr, sizeof(T));
bool result = 0 == memcmp(&expected, old, sizeof(T));
if (result) memcpy(ptr, &desired, sizeof(T));
else memcpy(&expected, old, sizeof(T));
return result;
```

Otherwise, equivalent to:

```
alignas(T) char old[sizeof(T)];
ulock->lock()
memcpy(old, ptr, sizeof(T));
bool result = 0 == memcmp(&expected, old, sizeof(T));
if (result) {
  memcpy(ptr, &desired, sizeof(T));
  ulock->unlock();
} else {
```

```
      ulock->unlock();
      memcpy(&expected, old, sizeof(T));
    }
    return result;
```

43 Let R be the return value of the operation. If and only if R is true, memory is affected according to the value of success, and if R is false, memory is affected according to the value of failure.

Retrieves the value in expected. It then atomically compares the value representation of the value referenced by *ptr for equality with that previously retrieved from expected, and if true, replaces the value referenced by *ptr with that in desired. When only one memory_order argument is supplied, the value of success is order, and the value of failure is order except that a value of memory_order_acq_rel shall be replaced by the value memory_order_acquire and a value of memory_order_release shall be replaced by the value memory_order_relaxed. If and only if the comparison is false then, after the atomic operation, the value in expected is replaced by the value read from the value referenced by *ptr during the atomic comparison. If ~~the operation returns~~R is true, these operations are atomic read-modify-write operations (??) on the value referenced by *ptr. Otherwise, these operations are atomic load operations on that memory.

44 *Returns:* The result of the comparison.

45 *Remarks:* A weak compare-and-exchange operation may fail spuriously. That is, even when the contents of memory referred to by expected and ptr are equal, it may return false and store back to expected the same memory contents that were originally there. [*Note*: This spurious failure enables implementation of compare-and-exchange on a broader class of machines, e.g., load-locked store-conditional machines. A consequence of spurious failure is that nearly all uses of weak compare-and-exchange will be in a loop. When a compare-and-exchange is in a loop, the weak version will yield better performance on some platforms. When a weak compare-and-exchange would require a loop and a strong one would not, the strong one is preferable. — *end note*]

Make the following changes in [atomics.ref.int].

```
namespace std {
  template<Lock> struct atomic_ref<integral, Lock> {
  private:
    integral* ptr;         // exposition only
    Lock* ulock; // exposition only
  public:
    using value_type = integral;
    using difference_type = value_type;
    static constexpr bool is_always_lock_free = implementation-defined;
    static constexpr bool never_requires_user_lock = implementation-defined;
    static constexpr size_t required_lock_free_alignment = implementation-defined;

    static bool is_lock_free(const T &) noexcept;
    static bool requires_user_lock(const T &) noexcept;

    atomic_ref& operator=(const atomic_ref&) = delete;

    explicit atomic_ref(T&) noexcept;
    atomic_ref(integral&, atomic_ref_assume_lock_free_t) noexcept;

    atomic_ref(integral&, Lock&) noexcept;
    atomic_ref(integral&, Lock&, atomic_ref_prefer_user_lock_t) noexcept;

    template<class Select> atomic_ref(integral&, ranges::RandomAccessRange<Lock>,
     Select = unspecified) noexcept;
    template<class Select> atomic_ref(integral&, ranges::RandomAccessRange<Lock>,
     atomic_ref_prefer_user_lock_t, Select = unspecified) noexcept;

    atomic_ref(const atomic_ref&) noexcept;
```

```
    integral operator=(integral) const noexcept;
    operator integral() const noexcept;

    bool is_lock_free() const noexcept;
    void store(integral, memory_order = memory_order_seq_cst) const noexcept;
    integral load(memory_order = memory_order_seq_cst) const noexcept;
    integral exchange(integral,
                      memory_order = memory_order_seq_cst) const noexcept;
    bool compare_exchange_weak(integral&, integral,
                               memory_order, memory_order) const noexcept;
    bool compare_exchange_strong(integral&, integral,
                                 memory_order, memory_order) const noexcept;
    bool compare_exchange_weak(integral&, integral,
                               memory_order = memory_order_seq_cst) const noexcept;
    bool compare_exchange_strong(integral&, integral,
                                 memory_order = memory_order_seq_cst) const noexcept;

    integral fetch_add(integral,
                       memory_order = memory_order_seq_cst) const noexcept;
    integral fetch_sub(integral,
                       memory_order = memory_order_seq_cst) const noexcept;
    integral fetch_and(integral,
                       memory_order = memory_order_seq_cst) const noexcept;
    integral fetch_or(integral,
                      memory_order = memory_order_seq_cst) const noexcept;
    integral fetch_xor(integral,
                       memory_order = memory_order_seq_cst) const noexcept;

    integral operator++(int) const noexcept;
    integral operator--(int) const noexcept;
    integral operator++() const noexcept;
    integral operator--() const noexcept;
    integral operator+=(integral) const noexcept;
    integral operator-=(integral) const noexcept;
    integral operator&=(integral) const noexcept;
    integral operator|=(integral) const noexcept;
    integral operator^=(integral) const noexcept;
  };
}
```

Make the following changes in [atomics.ref.float].

```
namespace std {
  template<Lock> struct atomic_ref<floating-point, Lock> {
  private:
    floating-point* ptr;  // exposition only
    Lock* ulock; // exposition only
  public:
    using value_type = floating-point;
    using difference_type = value_type;
    static constexpr bool is_always_lock_free = implementation-defined;
    static constexpr bool never_requires_user_lock = implementation-defined;
    static constexpr size_t required_lock_free_alignment = implementation-defined;

    static bool is_lock_free(const T &) noexcept;
    static bool requires_user_lock(const T &) noexcept;

    atomic_ref& operator=(const atomic_ref&) = delete;

    explicit atomic_ref(T&) noexcept;
    atomic_ref(floating-point&, atomic_ref_assume_lock_free_t) noexcept;

    atomic_ref(floating-point&, Lock&) noexcept;
    atomic_ref(floating-point&, Lock&, atomic_ref_prefer_user_lock_t) noexcept;
```

```
    template<class Select> atomic_ref(floating-point&, ranges::RandomAccessRange<Lock>,
     Select = unspecified) noexcept;
    template<class Select> atomic_ref(floating-point&, ranges::RandomAccessRange<Lock>,
     atomic_ref_prefer_user_lock_t, Select = unspecified) noexcept;

    atomic_ref(const atomic_ref&) noexcept;

    floating-point operator=(floating-point) noexcept;
    operator floating-point() const noexcept;

    bool is_lock_free() const noexcept;
    void store(floating-point, memory_order = memory_order_seq_cst) const noexcept;
    floating-point load(memory_order = memory_order_seq_cst) const noexcept;
    floating-point exchange(floating-point,
                            memory_order = memory_order_seq_cst) const noexcept;
    bool compare_exchange_weak(floating-point&, floating-point,
                               memory_order, memory_order) const noexcept;
    bool compare_exchange_strong(floating-point&, floating-point,
                                 memory_order, memory_order) const noexcept;
    bool compare_exchange_weak(floating-point&, floating-point,
                               memory_order = memory_order_seq_cst) const noexcept;
    bool compare_exchange_strong(floating-point&, floating-point,
                                 memory_order = memory_order_seq_cst) const noexcept;

    floating-point fetch_add(floating-point,
                             memory_order = memory_order_seq_cst) const noexcept;
    floating-point fetch_sub(floating-point,
                             memory_order = memory_order_seq_cst) const noexcept;

    floating-point operator+=(floating-point) const noexcept;
    floating-point operator-=(floating-point) const noexcept;
  };
}
```

Make the following changes in [atomics.ref.pointer].

```
namespace std {
  template<class T, Lock> struct atomic_ref<T*, Lock> {
  private:
    T** ptr;                // exposition only
    Lock* ulock; // exposition only
  public:
    using value_type = T*;
    using difference_type = ptrdiff_t;
    static constexpr bool is_always_lock_free = implementation-defined;
    static constexpr bool never_requires_user_lock = implementation-defined;
    static constexpr size_t required_lock_free_alignment = implementation-defined;

    static bool is_lock_free(const T &) noexcept;
    static bool requires_user_lock(const T &) noexcept;

    atomic_ref& operator=(const atomic_ref&) = delete;

    explicit atomic_ref(T&) noexcept;
    atomic_ref(T*, atomic_ref_assume_lock_free_t) noexcept;

    atomic_ref(T*, Lock&) noexcept;
    atomic_ref(T*, Lock&, atomic_ref_prefer_user_lock_t) noexcept;

    template<class Select> atomic_ref(T*, ranges::RandomAccessRange<Lock>,
     Select = unspecified) noexcept;
    template<class Select> atomic_ref(T*, ranges::RandomAccessRange<Lock>,
     atomic_ref_prefer_user_lock_t, Select = unspecified) noexcept;
```

```
    atomic_ref(const atomic_ref&) noexcept;

    T* operator=(T*) const noexcept;
    operator T*() const noexcept;

    bool is_lock_free() const noexcept;
    void store(T*, memory_order = memory_order_seq_cst) const noexcept;
    T* load(memory_order = memory_order_seq_cst) const noexcept;
    T* exchange(T*, memory_order = memory_order_seq_cst) const noexcept;
    bool compare_exchange_weak(T*&, T*,
                               memory_order, memory_order) const noexcept;
    bool compare_exchange_strong(T*&, T*,
                                 memory_order, memory_order) const noexcept;
    bool compare_exchange_weak(T*&, T*,
                               memory_order = memory_order_seq_cst) const noexcept;
    bool compare_exchange_strong(T*&, T*,
                                 memory_order = memory_order_seq_cst) const noexcept;

    T* fetch_add(difference_type, memory_order = memory_order_seq_cst) const noexcept;
    T* fetch_sub(difference_type, memory_order = memory_order_seq_cst) const noexcept;

    T* operator++(int) const noexcept;
    T* operator--(int) const noexcept;
    T* operator++() const noexcept;
    T* operator--() const noexcept;
    T* operator+=(difference_type) const noexcept;
    T* operator-=(difference_type) const noexcept;
  };
}
```