Generalized Abstract `GHC.Generics`

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GHC.Generics

GHC's most popular datatype-generic programming library.

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  | MkADT2 a
 deriving Generic
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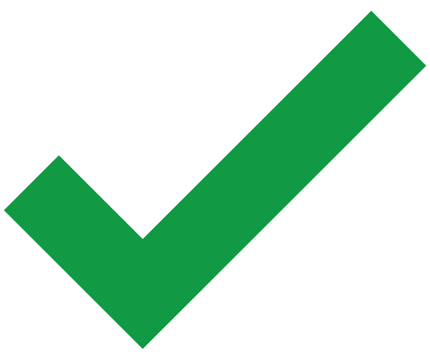

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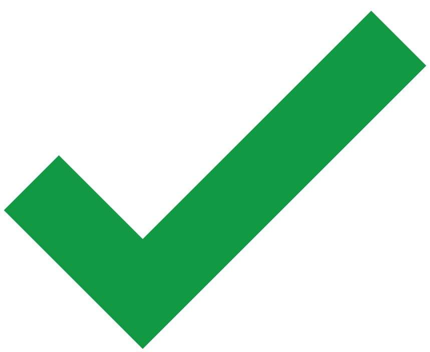

```haskell
data GADT a where
  MkGADT1 :: GADT Int
  MkGADT2 :: GADT Bool
 deriving Generic
```

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```
data ADT a
  = MkADT1 a
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 deriving Generic
```

✓

```
data GADT a where
  MkGADT1 :: GADT Int
  MkGADT2 :: GADT Bool
 deriving Generic
```

✗

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```
class Generic a where -- Can be derived
  type Rep a
  from :: a -> Rep a
  to   :: Rep a -> a
```

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```
class NFData a where
  rnf :: a -> ()

instance NFData a => NFData [a] where
  rnf []       = ()
  rnf (x:xs) = rnf x `seq` rnf xs
```

We'll continue to use NFData as a running example.

What can `GHC.Generics` do?

Generically represent any (simple) algebraic data type as a composition of *representation types*.

```
data U1 = U1                       -- No fields
newtype K1 c = K1 c                -- One field
data a :*: b = a :*: b             -- Products
data a :+: b = L1 a | R1 b         -- Sums
```

What can `GHC.Generics` do?

Generically represent any (simple) algebraic data type as a composition of *representation types*.

```haskell
-- Example instance
instance Generic [a] where
  type Rep [a] =
        U1                        -- []  constructor
    :+: (K1 a :*: K1 [a]) -- (:) constructor

  from []     = L1 U1
  from (x:xs) = R1 (K1 x :*: K1 xs)
  to (L1 U1)              = []
  to (R1 (K1 x :*: K1 xs)) = x:xs
```

What can `GHC.Generics` do?

Generically represent any (simple) algebraic data type as a composition of *representation types*.

```
instance NFData U1 where
  rnf U1 = ()

instance NFData c => NFData (K1 c) where
  rnf (K1 c) = rnf c
```

What can `GHC.Generics` do?

Generically represent any (simple) algebraic data type as a composition of *representation types*.

```
instance (NFData a, NFData b)
    => NFData (a :*: b) where
  rnf (x :*: y) = rnf x `seq` rnf y

instance (NFData a, NFData b)
    => NFData (a :+: b) where
  rnf (L1 x) = rnf x
  rnf (R1 y) = rnf y
```

What can `GHC.Generics` do?

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```
instance NFData a => NFData [a] where
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genericRNF :: (Generic a, NFData (Rep a))
           => a -> ()
genericRNF x = rnf (from x)
```

What can `GHC.Generics` do?

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instance NFData a => NFData [a] where
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genericRNF :: (Generic a, NFData (Rep a))
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genericRNF x = rnf (from x)
```

What *can't* `GHC.Generics` do?

It can't represent GADTs… but why not?

What *can't* `GHC.Generics` do?

```
data GADTEx :: Type -> Type -> Type where
  GADTEx1 :: NFData a => a -> GADTEx a b
  GADTEx2 :: NFData b => b -> GADTEx a b
```

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  GADTEx1 :: NFData a => a -> GADTEx a b
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```

```haskell
-- Like to be able to derive this:
instance NFData (GADTEx a b) where
  rnf (GADTEx1 x) = rnf x
  rnf (GADTEx2 y) = rnf y
```

What *can't* GHC.Generics do?

```
data GADTEx :: Type -> Type -> Type where
  GADTEx1 :: NFData a => a -> GADTEx a b
  GADTEx2 :: NFData b => b -> GADTEx a b
```

```
-- Attempt 1
instance (NFData a, NFData b)
    => Generic (GADTEx a b) where
  type Rep (GADTEx a b) = K1 a :+: K1 b

  from (GADTEx1 x) = L1 (K1 x)
  from (GADTEx2 y) = R1 (K1 y)
  to (L1 (K1 x)) = GADTEx1 x
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```
-- Attempt 1 (continued)
instance (NFData a, NFData b)
    => NFData (GADTEx a b) where
  rnf = genericRNF
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```

```
-- Attempt [illegible] continu[illegible]
instance (NFD[illegible] a, [illegible]ata b)
    => NFData ([illegible] a b) where
  rnf = generic[illegible]
```

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instance (NFData a, NFData b)
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Solution: invent a new representation type

We need to generically represent constructors with existential contexts.

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```
data ExConstr
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instance (c => NFData x)
    => NFData (ExConstr c x) where
  rnf (ExConstr x) = rnf x
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data ExConstr
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QuantifiedConstraints! (New in GHC 8.6)

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data GADTEx :: Type -> Type -> Type where
  GADTEx1 :: NFData a => a -> GADTEx a b
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```

```haskell
-- Attempt 2
instance Generic (GADTEx a b) where
  ...
```

What *can't* GHC.Generics do?

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data GADTEx :: Type -> Type -> Type where
  GADTEx1 :: NFData a => a -> GADTEx a b
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```

```haskell
-- Attempt 2
instance Generic (GADTEx a b) where
  type Rep (GADTEx a b) =
        ExConstr (NFData a) (K1 a)
    :+: ExConstr (NFData b) (K1 b)
  from (GADTEx1 x) = L1 (ExConstr (K1 x))
  from (GADTEx2 y) = R1 (ExConstr (K1 y))
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  GADTEx2 :: NFData b => b -> GADTEx a b
```

```haskell
-- Attempt 2 (continued)
instance NFData (GADTEx a b) where
  rnf = genericRNF
```

What ~~can't~~ *can* GHC.Generics do?

```haskell
data GADTEx :: Type -> Type -> Type where
  GADTEx1 :: NFData a => a -> GADTEx a b
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```

```haskell
-- Attempt 2 (continued)
instance NFData (GADTEx a b) where
  rnf = genericRNF
```

What about type indices?

```
data GADTEx :: Type -> Type -> Type where
  -- ...
  GADTEx3 :: Int -> Bool -> GADTEx Int Bool
```

What about type indices?

```
data GADTEx :: Type -> Type -> Type where
  -- This...
  GADTEx3 :: Int -> Bool -> GADTEx Int Bool

  -- ...is wholly equivalent to this:
  GADTEx3 :: (a ~ Int, b ~ Bool)
          => Int -> Bool -> GADTEx a b
```

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data GADTEx :: Type -> Type -> Type where
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data GADTEx :: Type -> Type -> Type where
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  -- ...is wholly equivalent to this:
  GADTEx3 :: (a ~ Int, b ~ Bool)
          => Int -> Bool -> GADTEx a b
```

What about existentially quantified type variables?

```
data SomeNFThing :: Type where
  SomeNFThing :: forall a. NFData a
              => a -> SomeNFThing
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What about existentially quantified type variables?

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data SomeNFThing :: Type where
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```

We'd like to be able to write something like this:

```haskell
instance Generic SomeNFThing where
  type Rep SomeNFThing =
    ExQuant (\a -> ExConstr (NFData a) (K1 a))
         -- ^ Type-level lambda
```

Faking type-level lambdas

```
data SomeNFThing :: Type where
  SomeNFThing :: forall a. NFData a
              => a -> SomeNFThing
```

```
instance Generic SomeNFThing where
  type Rep SomeNFThing =
    ExQuant RepAux

type RepAux (a :: Type) =
  ExConstr (NFData a) (K1 a)
```

Faking type-level lambdas

```
data SomeNFThing :: Type where
  SomeNFThing :: forall a. NFData a
              => a -> SomeNFThing
```

```
instance Generic SomeNFThing where
  type Rep SomeNFThing =
    ExQuant RepAux

type RepAux (a :: Type) =
  ExConstr (NFData a) (K1 a)
```

Can’t partially apply type synonyms :(

Solution: defunctionalization

(Reynolds 1972, Eisenberg and Stolarek 2014)

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```
type a ~> b = a -> b -> Type
type family
  Apply (f :: Type ~> Type) (x :: a) :: b
```

Solution: defunctionalization

(Reynolds 1972, Eisenberg and Stolarek 2014)

```
type a ~> b = a -> b -> Type
type family
  Apply (f :: Type ~> Type) (x :: a) :: b

type RepAux (a :: Type) =
  ExConstr (NFData a) (K1 a)
```

Solution: defunctionalization

(Reynolds 1972, Eisenberg and Stolarek 2014)

```
type a ~> b = a -> b -> Type
type family
  Apply (f :: Type ~> Type) (x :: a) :: b

type RepAux (a :: Type) =
  ExConstr (NFData a) (K1 a)
data RepAuxSym :: Type ~> Type
type instance Apply RepAuxSym a = RepAux a
```

Solution: defunctionalization

(Reynolds 1972, Eisenberg and Stolarek 2014)

```
data ExQuant :: (Type ~> Type) -> Type where
  ExQuant
    :: forall f x.
                -- ^ x is existential
                Apply f x -> ExQuant f
```

Solution: defunctionalization

(Reynolds 1972, Eisenberg and Stolarek 2014)

```
instance (forall x. NFData (Apply f x))
    => NFData (ExQuant f) where
  rnf (ExQuant x) = rnf x
```

Solution: defunctionalization

(Reynolds 1972, Eisenberg and Stolarek 2014)

```
instance (forall x. NFData (Apply f x))
    => NFData (ExQuant f) where
  rnf (ExQuant x) = rnf x
```

Solution: defunctionalization

(Reynolds 1972, Eisenberg and Stolarek 2014)

```
instance (forall x. NFData (Apply f x))
    => NFData (ExQuant f) where
  rnf (ExQuant x) = rnf x
```

• Illegal type synonym family application in instance: Apply f x

Solution: defunctionalization

(Reynolds 1972, Eisenberg and Stolarek 2014)

```
data ExQuant :: (Type ~> Type) -> Type where
  ExQuant
    :: forall f x.
              -- ^ x is existential
              Apply f x          -> ExQuant f
```

Solution: defunctionalization

(Reynolds 1972, Eisenberg and Stolarek 2014)

```
data ExQuant :: (Type ~> Type) -> Type where
  ExQuant
    :: forall f x.
                -- ^ x is existential
                WrappedApply f x -> ExQuant f

newtype WrappedApply f x =
  WrapApply (Apply f x)
```

Solution: defunctionalization

(Reynolds 1972, Eisenberg and Stolarek 2014)

```
instance
       (forall x. NFData (Apply f x))
    => NFData (ExQuant f) where
  rnf (ExQuant x) = rnf x
```

Solution: defunctionalization

(Reynolds 1972, Eisenberg and Stolarek 2014)

```
instance
       (forall x. NFData (WrappedApply f x))
    => NFData (ExQuant f) where
  rnf (ExQuant x) = rnf x
```

Solution: defunctionalization

(Reynolds 1972, Eisenberg and Stolarek 2014)

```
instance
       (forall x. NFData (WrappedApply f x))
    => NFData (ExQuant f) where
  rnf (ExQuant x) = rnf x

instance NFData (Apply f x)
    => NFData (WrappedApply f x) where
  rnf (WrapApply x) = rnf x
```

Faking type-level lambdas

```
data SomeNFThing :: Type where
  SomeNFThing :: forall a. NFData a
              => a -> SomeNFThing
```

```
instance Generic SomeNFThing where
  type Rep SomeNFThing =
    ExQuant ???

type RepAux (a :: Type) =
  ExConstr (NFData a) (K1 a)
```

Faking type-level lambdas

```
data SomeNFThing :: Type where
  SomeNFThing :: forall a. NFData a
              => a -> SomeNFThing
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```
instance Generic SomeNFThing where
  type Rep SomeNFThing =
    ExQuant RepAuxSym

type RepAux (a :: Type) =
  ExConstr (NFData a) (K1 a)
```

Faking type-level lambdas

```
data SomeNFThing :: Type where
  SomeNFThing :: forall a. NFData a
              => a -> SomeNFThing
```

```
instance Generic SomeNFThing where
  type Rep SomeNFThing =
    ExQuant RepAuxSym
  from (SomeNFThing x) =
    ExQuant (WrapApply (ExConstr (K1 x)))
  to (ExQuant (WrapApply (ExConstr (K1 x)))) =
    SomeNFThing x
```

Faking type-level lambdas

```
data SomeNFThing :: Type where
  SomeNFThing :: forall a. NFData a
              => a -> SomeNFThing
```

```
instance NFData SomeNFThing where
  rnf = genericRNF
```

Faking type-level lambdas

```haskell
data SomeNFThing :: Type where
  SomeNFThing :: forall a. NFData a
              => a -> SomeNFThing
```

```haskell
instance NFData SomeNFThing where
  rnf = genericRNF
```

Can we ditch defunctionalization?

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- Not today… but maybe tomorrow!
  - Type-level lambdas (Eisenberg 2016)

  - Unsaturated type synonyms (Kiss 2018)

Related work

- *The Gentle Art of Levitation* (Chapman *et al*. 2010)
  - *The Practical Guide to Levitation* (Al-Sibahi 2014)
- *Generic Programming of All Kinds* (Serrano and Miraldo 2018)

Open questions

- Rank-*n* types
  - ```
    data Foo :: Type where
      MkFoo :: forall b. ((forall a. a -> a) -> b -> b)
            -> Foo
    ```
- Performance
    ```

Takeaways

- With these extensions, `deriving Generic` would work for ADTs and GADTs alike
- No breaking changes to `GHC.Generics` required
- Some parts are hairy… but could be made less so with the help of ongoing work in GHC

Template Haskell prototype:

https://github.com/dreixel/generic-deriving/tree/experimental