

MakeNoise<MapDomain<AtomDomain<TK>, AtomDomain<TV>, LOPi<P, AbsoluteDistance<QI>, MO> for IntExpFamily<P>

Michael Shoemate

This proof resides in “**contrib**” because it has not completed the vetting process.

Proves soundness of the implementation of **MakeNoiseThreshold** over hashmaps for IntExpFamily in **mod.rs** at commit **f5bb719** (outdated<sup>1</sup>).

This mechanism samples from the IntExpFamily distribution, where the tails are clipped to the smallest and largest representable integers in the native integer type. This is done by first sampling from the ZExpFamily, the equivalent distribution supported on all integers, and then clipping the tails by clamping. The clamping is done by saturating the cast of the sampled value to the native integer type.

## 1 Hoare Triple

### Precondition

#### Compiler-Verified

- Generic T implements trait **Integer** and **SaturatingCast**<IBig> The saturating cast is for infallible postprocessing of big ints back to type T.
- Const-generic P is of type **usize**
- Generic QI implements trait **Integer**
- Generic MO implements trait **Measure**
- Type IBig implements trait **From**<T>. This infallible exact cast is for converting integers to big ints in the preprocessing transformation.
- Type RBig implements trait **TryFrom**<QI>. This is for fallible casting from input sensitivity of type QI to a rational in the privacy map.
- Type ZExpFamily<P> implements trait **NoisePrivacyMap**<LpDistance<P, RBig>, MO>. This bound requires that it must be possible to construct a privacy map for this combination of noise distribution, distance type and privacy measure.

#### User-Verified

None

---

<sup>1</sup>See new changes with `git diff f5bb719..cb770fc5 rust/src/measurements/noise_threshold/nature/integer/mod.rs`

## Pseudocode

```
1 class IntExpFamily:
2     def make_noise_threshold(
3         self,
4         input_space: tuple[
5             MapDomain[AtomDomain[TK], AtomDomain[TV]], LOPI[P, AbsoluteDistance[QI]]
6         ],
7         threshold: TV,
8     ) -> Measurement[
9         MapDomain[AtomDomain[TK], AtomDomain[TV]],
10        HashMap[TK, TV],
11        LOPI[P, AbsoluteDistance[QI]],
12        MO,
13    ]:
14        distribution = ZExpFamily(
15            scale=integerize_scale(self.scale, 0)
16        ) #
17
18        threshold = UBig.try_from(threshold)
19
20        t_int = make_int_to_bigint_threshold(input_space)
21        m_noise = distribution.make_noise_threshold(t_int.output_space())
22        f_native_int = then_saturating_cast_hashmap()
23
24        return t_int >> m_noise >> f_native_int
```

## Postcondition

### Theorem 1.1.

**Theorem 1.2.** For every setting of the input parameters (`self`, `input_space`, `threshold`, `MO`, `TK`, `TV`, `P`, `QI`) to `make_noise_threshold` such that the given preconditions hold, `make_noise_threshold` raises an exception (at compile time or run time) or returns a valid measurement. A valid measurement has the following property:

1. (Privacy guarantee). For every pair of elements  $x, x'$  in `input_domain` and for every pair  $(d_{in}, d_{out})$ , where  $d_{in}$  has the associated type for `input_metric` and  $d_{out}$  has the associated type for `output_measure`, if  $x, x'$  are  $d_{in}$ -close under `input_metric`, `privacy_map(d_in)` does not raise an exception, and `privacy_map(d_in) ≤ d_out`, then `function(x), function(x')` are  $d_{out}$ -close under `output_measure`.

*Proof.* Line 16 constructs a new random variable following a distribution equivalent to `IntExpFamily`, but without clipped tails.

Neither constructor `make_int_to_bigint_threshold` nor `MakeNoiseThreshold.make_noise_threshold` have manual preconditions, and the postconditions guarantee a valid transformation and valid measurement, respectively. `then_saturating_cast_hashmap` also does not have preconditions, and its postcondition guarantees that it returns a valid postprocessor.

The chain of a valid transformation, valid measurement and valid postprocessor is a valid measurement.  $\square$