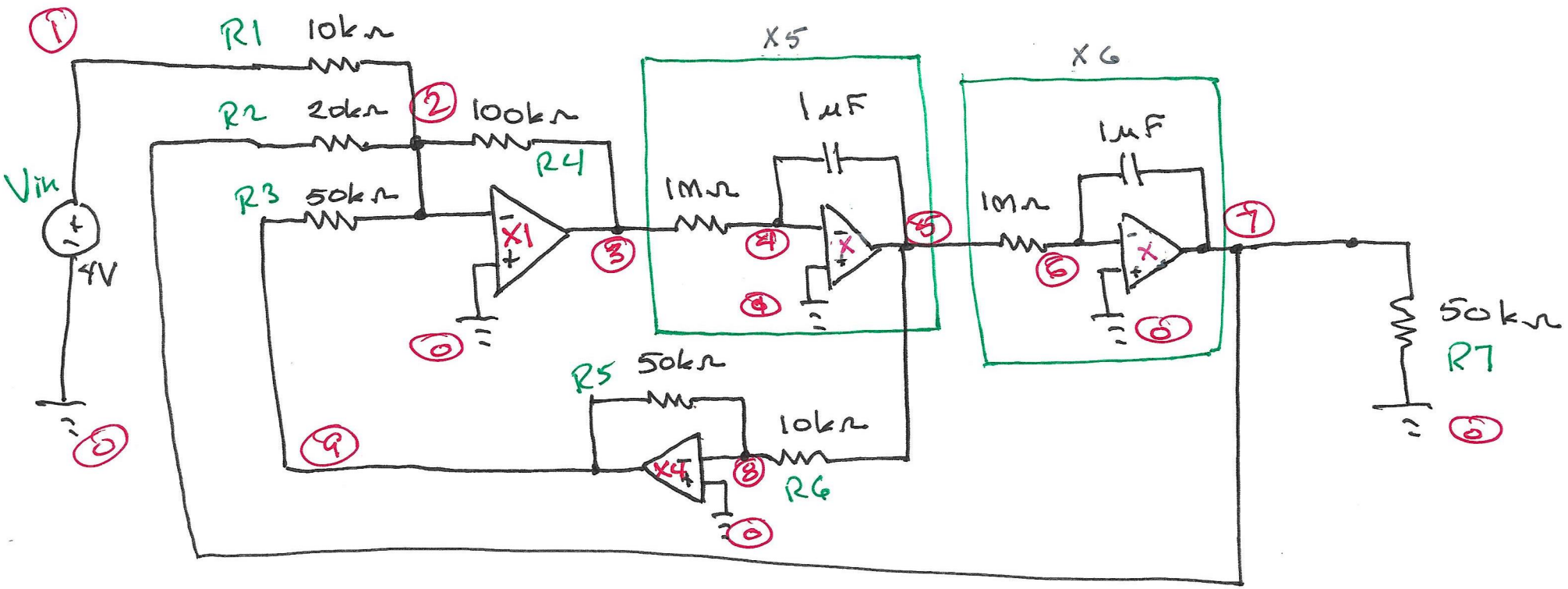
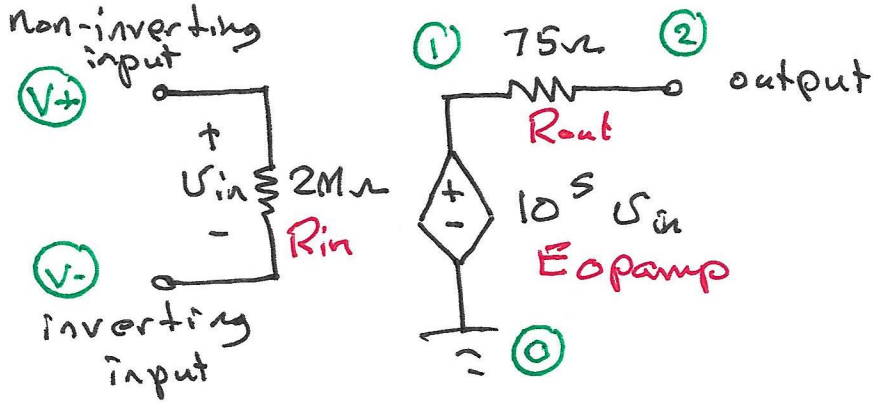
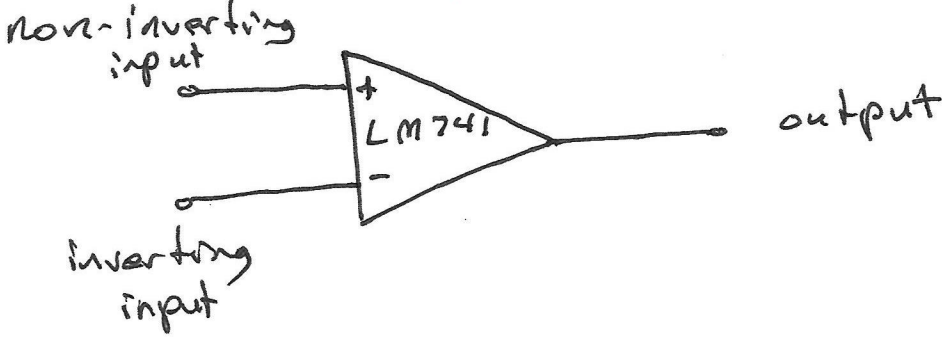


Each opamp is a LM741 opamp from National Semiconductor.

Simulate with LTspice

Define a subcircuit for the LM741 opamp.

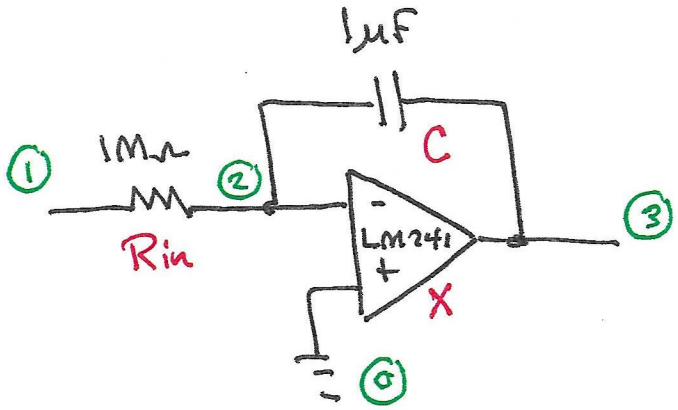




Subcircuit definition for the opamp:

```
.subckt LM741  V+  V-  2
Rin  V+  V-  2MEG
Eopamp  1  0  V+  V-  1E5
Rout  1  2  75
.ends
```

For the integrator:



Subcircuit definition:

```
.subckt   integrator   1   3
Rin   1   2   1MEG
C   2   3   1u
X   0   2   3   LM741
.ends
```

Using the subcircuits just discussed:

~~TITLE~~ automatically inserted by LTspice

```
Vin     1     0     DC     4
R1      1     2     10k
R2      7     2     10k
R3      9     2     10k
R4      2     3     100k
X1      0     2     3     LM741
X5      3     5     integrator
X6      5     7     integrator
R7      7     0     50k
R5      9     8     50k
R6      8     5     10k
X4      0     8     9     LM741
```

```
.subckt   LM741   V+   V-   2
Rin   V+   V-   2MEG
Eopamp   1   0   V+   V-   1E5
Rout   1   2   75
.ends
```

insert the LM741 subcircuit once

```
.subckt   integrator   1   3
Rin   1   2   1MEG
C   2   3   1u
X   0   2   3   LM741
.ends
```

insert the integrator subcircuit once

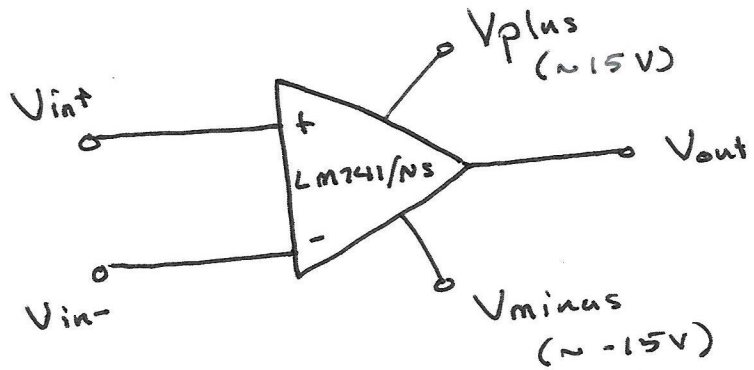
```
.op
```

~~.end~~ automatically inserted by LTspice

Download and install the LM741.MOD model.

Documents\LTspice XVII\sub\LM741.MOD

This model requires 5 connections:



Using the National Semiconductor model for the LM741:

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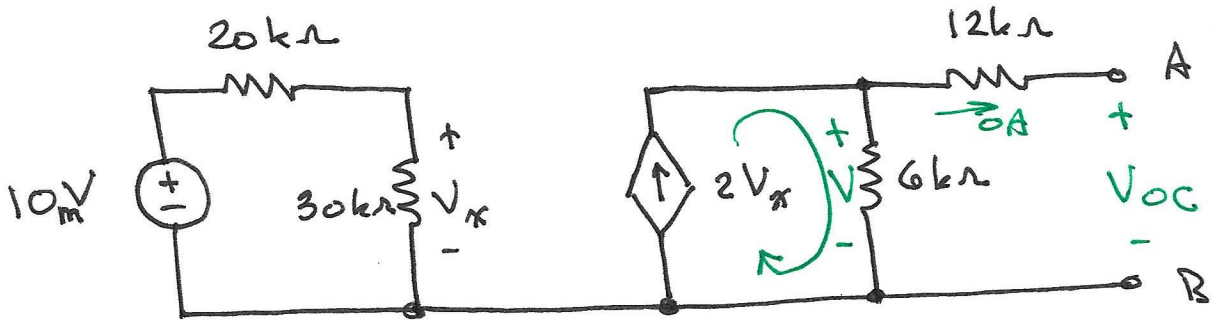
```
Vin     1     0     DC     4
R1      1     2     10k
R2      7     2     10k
R3      9     2     10k
R4      2     3     100k
X1      0     2     V+     V-     3     LM741/NS
X5      3     5     V+     V-     integrator
X6      5     7     V+     V-     integrator
R7      7     0     50k
R5      9     8     50k
R6      8     5     10k
X4      0     8     V+     V-     9     LM741/NS

V+15    V+    0     DC     15
V-15    V-    0     DC     -15

.LIB    LM741.MOD

.subckt integrator  1     3     V+15   V-15
Rin     1     2     1MEG
C       2     3     1u
X       0     2     V+15   V-15   3     LM741/NS
.ends
.op
```

~~.end~~ automatically inserted by LTspice

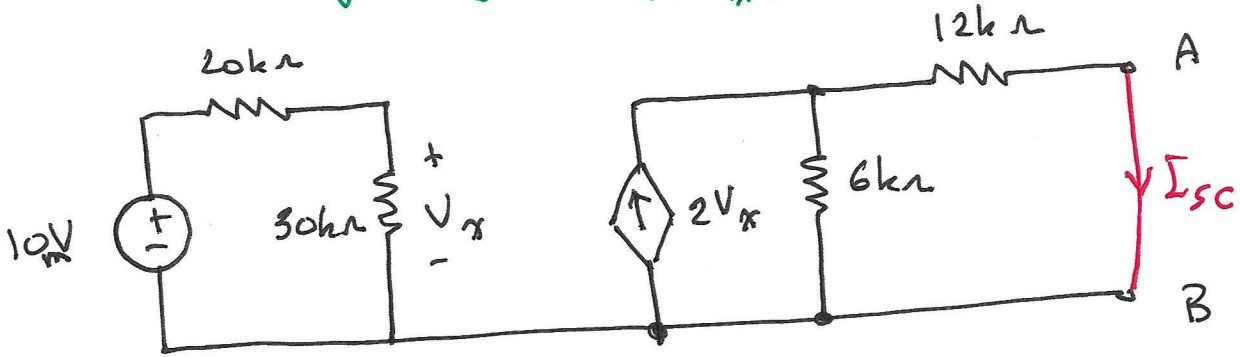
Find the Thévenin equivalent circuit w.r.t. terminals A, B



$V_x = \frac{3}{5}\,10mV = 6\,mV$

$2V_x = 12\,mA$

$V = (6k\Omega)(2V_x) = 72\,V = V_{oc}$

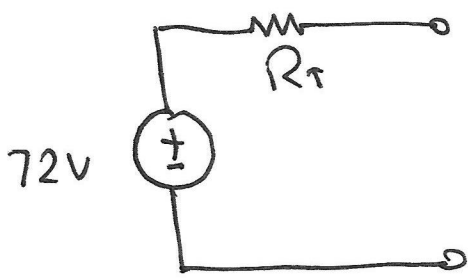


$V_x = 6\,mV$

$2V_x = 12\,mA$

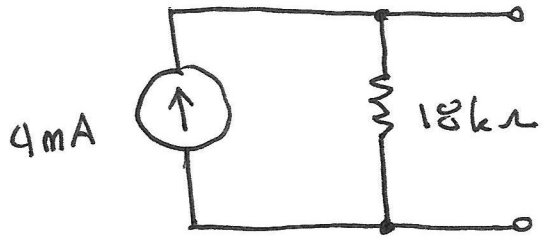
$I_{SC} = \frac{6}{18}(12mA) = 4\,mA$

Thévenin equivalent:

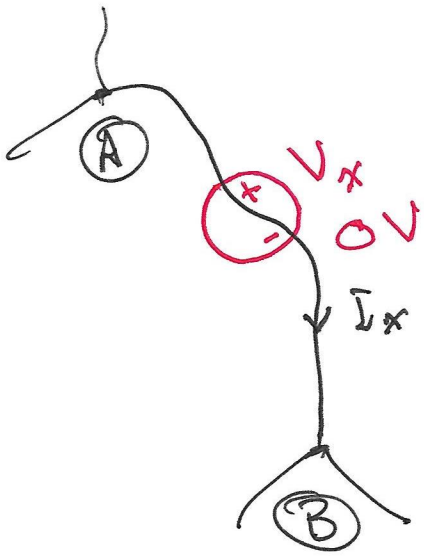


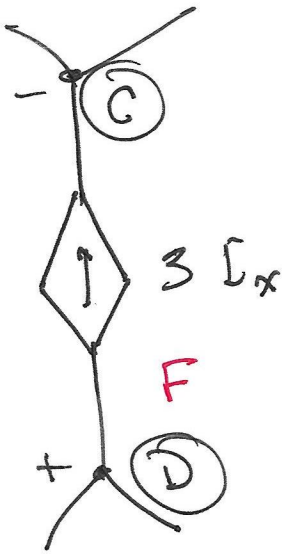
$$R_T = \frac{V_{oc}}{I_{sc}} = \frac{72\,V}{4\,mA} = 18\,k\Omega$$

Norton equivalent:



CCCS





F	D	C	V_x	3
V_x	A	B	DC	0

VCVS	E
CCCS	F ✓
VCCS	G
CCVS	H ✓